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432494

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Baton Rouge, Louisiana 70801-1780

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DEPARTMENT OF TRANSPORTATION

98 AUG 10 PM 3:45

4P967  
July 28, 1998  
RECEIVED SECTION

RSPA 98-4309-1

Associate Administrator for Hazardous Materials Safety  
Research and Special Programs Administration  
U. S. Department of Transportation  
400 7th Street, S. W.  
Washington, DC 20590-000 1

Attention: Exemptions, DHM-3 1

Dear Sir:

Albemarle Corporation requests a combination exemption and approval from certain provisions of 49 CFR to allow the shipment of hazardous solids in a non-specification portable tanks. An approval is necessary because of the requirements of certain foreign countries for this document. DOT has issued combination exemption approvals in the past in similar circumstances and such a document is requested here. Inasmuch as an exemption and separate approval already exist for almost identical tanks, we believe that though a separate issue, the matter has been already addressed by the earlier exemption and approval and this request does not constitute new matter. In this regard, we request that priority be given to this request since it does not suppose any necessity for new evaluation by DOT. A copy of the earlier exemption and approval are enclosed.

1. Applicant

Albemarle Corporation  
45 1 Florida Street  
Baton Rouge, LA 70801  
Contact: Jack E. Helms (504-388-7752)

2. Purpose and Limitation

- a. This request is to authorize the transportation in commerce of certain pyrophoric solids (Metallocenes) in a non-DOT specification portable tank comparable to a specification DOT 5 1 portable tank.
- b. Our safety analyses considered the hazards and risks associated with transportation in commerce. In addition note that the tanks were designed and evaluated to facilitate loading at Albemarle's facility and unloading at customer facilities.

c. This exemption is based on a nearly identical exemption issued earlier, DOT-E 11970, except that this tank is less than half the size and is stronger than the earlier approved vessel. An approval has also been issued (CA-9806007) for the tanks covered by DOT-E 11970.

3. Regulatory System Affected: 49 CFR Parts 106, 107, and 171- 180.
4. Regulations from Which Exemption is Sought: 49 CFR 173.242 in that a non-DOT specification portable tank is to be used; § 178.245-1 (c) in that all openings are not grouped in one location; § 178.245-1(d) (4) in that the tank is not in a full framework for containerization and to allow a bottom discharge opening with no internal stop-valve.
5. Basis: request is submitted in accordance with 49 CFR 107.105.
6. Hazardous Materials (49 CFR 172.101):

<b>Hazardous materials description - proper shipping name</b>	<b>Hazard Class/ Division</b>	<b>Identifi- cation Number</b>	<b>Packing Group</b>
Pyrophoric organometallic compound, n. o. s. (Metallocenes)	4. 2	<b>UN3203</b>	I
Pyrophoric solid, inorganic, n. o. s. (Metallocenes)	4. 2	<b>UN3200</b>	I
Water-reactive solid, n. o. s. (Metallocenes)	4. 3	<b>UN2813</b>	I
Organometallic compound, water-reactive, flammable, n. o. s. (Metallocenes)	4.3	<b>UN3207</b>	I

7. Packaging and Safety Control Measures:

a. Packaging - Packaging is a non-DOT specification stainless steel portable tank conforming to the configuration and dimensions shown in Hebeler Corporation Drawing D-1099-1 0 Rev. 2 dated March 3, 1998 attached to this application. The portable tank has

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- a minimum wall thickness of 9.5 mm (0.375 in);
- maximum allowable working pressure of 8.62 bar (125 psig);
- capacity not to exceed 803 L (212 gal);
- tare mass of 519 kgs (1144 lbs);
- cone-shaped funnel bottom with a an eductor and block valves;
- maximum loading or discharge pressure of 3.5 bar (50 psig); and
- spring loaded pressure relief valve set at 8.62 bar (125 psig).

In addition, the portable tank conforms with specification DOT 5.1 (49 CFR 178.245) except as follows:

1. § 178.245-1(c). The tank has a bottom discharge fitted with an eductor and block valves in addition to openings on the top of the tank.
  2. § 178.245-1 (d) (4). The portable tank is not mounted in a full framework for containerized transport and the bottom discharge is not fitted with an internal self-closing stop-valve.
- b. Testing: - Each portable tank will be tested and retested and reinspected as required for a DOT 5.1 portable tank. Minimum test pressure is 12.93 bar (187.5 psig).
- c. Operating Controls: -
- i. The bottom valves will be blind flanged during transportation.
  - ii. A dry nitrogen blanket of 0.7 bar (10 psig) will be provided for transportation of the metallocenes.
8. Modes of Transportation Requested: Motor vehicle and cargo vessel.

Enclosed with this application are a copy of the tank fabrication drawing, an assembly drawing and the ASME Code calculations.

Under special provisions it is requested that the following text be included:

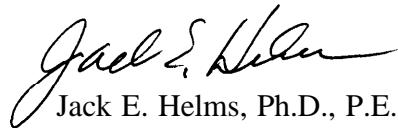
This exemption serves as a Competent Authority Approval (CA-98XXXXXX) issued by the Associate Administrator for Hazardous Materials Safety, Research and Special Programs Administration of the United States Department of Transportation, in

Associate Administrator for Hazardous Materials Safety  
July 28, 1998  
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accordance with Section 10.3 of the General Introduction of the International Maritime Dangerous Goods Code.

If any opposition to this request is registered, we request copies of such filings subject to your fee schedule. If such filings are made, we request the opportunity of an informal discussion with your staff.

Yours very truly,



Jack E. Helms, Ph.D., P.E.  
Advisor, Transportation

cc: M. V. Wall  
G. W. Rousseau - HMT Associates

7-05-1998 9:34AM

FROM HMT ASSOCIATES LLC 202 463 3512

P. 2

JUL-06-1998 09: 27

RSPA/RAHMS

2023663753 P.02/05



U.S. Department  
of Transportation

Research and  
Special Programs  
Administration

400 Seventh Street, S.W.  
Washington, D.C. 20590

JUN 5 1998

DOT-E 11970

**EXPIRATION DATE: May 15, 2000**

(FOR **RENEWAL**, SEE 49 CFR SECTION 107.109).

1. GRANTEE: **Exxon Chemical, Inc.**  
**Baytown, Texas**

2. **PURPOSE AND LIMITATION:**

- a. This exemption authorizes **the** transportation in commerce of certain **pyrophoric** solids in a non-DOT specification portable tank comparable to a specification DOT **51** portable tank. This exemption provides no relief from any regulation-other than as specifically stated herein,
- b. The safety analyses performed in development of this exemption only **considered** the hazards and risks associated with transportation **in commerce**. The safety analyses did not consider the hazards and risks associated **with** consumer use, use **as** a component of a **transport** vehicle **or other** device, or other uses not associated with transportation **in commerce**.

3. **REGULATORY SYSTEM AFFECTED:** 49 CFR Parts 106, 107 and 171-180.

4. **REGULATIONS FROM WHICH EXEMPTED:** 49 CFR 173.242 in that a non-DOT specification portable tank **is** authorized; **§ 178.245-1(c)** in that all openings are **not** grouped **in one** location; and **§ 178.245-1(d) (4)** in that the tank is not **in a** full framework for containerization and to allow a **bottom** discharge opening with no internal stop-valve.

5. **BASIS:** This exemption is based on the application of **Exxon** Chemical, Inc., dated September 30, 1997, and supplemental information dated October 21, 1997 and May **13**, 1998, submitted in accordance with 49 CFR 107.105 and the **public** proceeding thereon.

7-05-1998 9:35AM

FROM HMT ASSOCIATES LLC 202 A63 3512

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RSPA/RAHMS

2023663753 P.03/05

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Continuation of DOT-E 11970

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6. HAZARDOUS MATERIALS (49 CFR 172.101):

Hazardous materials description -- proper shipping name	Hazard Class/ Division	Identifi- cation Number	Packing Group
Pyrophoric solid, inorganic, N.O.S.	4.2	UN3200	I

For the N.O.S entry above, the requirements of 49 CFR 172.203(k) must be met.

7. PACKAGING AND SAFETY CONTROL MEASURES:

a. **PACKAGING** - Packaging is a non-DOT specification steel **portable** tank conforming to the configuration and dimensions shown in Buckeye Boiler Drawing No. **83-0110** Rev. 3 dated **2/94** on file with the Office of **Hazardous** Materials Exemptions and Approvals. The **portable** tank has:

- a minimum wall thickness of 6.35 mm;
- maximum **allowable** working pressure of 110 psig;
- capacity not to exceed 2047 liters (540 gallons);
- **tare mass of 1360 kqs**;
- cone-shaped funnel **bottom with** a ball valve;
- maximum loading or discharge pressure of **75 psig**; and
- spring loaded pressure relief ~~set~~ set at 110 psig.

In addition, the **portable tank** must *conform with* specification DOT **51** (49 CFR 178.24%) except as follows:

1. **S 178.245-1(c)**. The tank-has a **bottom** discharge fitted with a ball valve in addition to opening on the top of the tank.

2. **S 178.245-1(d)(4)**. The portable tank is not **mounted in a full framework for containerized transport** and the bottom discharge **is not** fitted with an internal self-closing stop-valve.

3. **S 178.245-7(a)**. The line on the name plate **which** reads "DOT specification-No." must be marked "DOT-E 11970".

b. **TESTING** - Each portable 'tank **must tested** and retested and reinspected as required for a DOT **51** portable **tank**. Minimum test pressure is **165 psig**.

7-05-1998 9:36AM

FROM HMT ASSOCIATES LLC 202 463 3512

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RSPA/RAHMS

202 366 3753 P.04/05

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Continuation of DOT-E 11970

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c. OPERATIONAL CONTROLS -

i. The 1" bottom ball valve must be plugged and protected from side impact during **transportation**.

ii. A dry **nitrogen** blanket **of** 22 psig must be provided for transportation of pyrophoric solid material.

8. SPECIAL PROVISIONS:

a. Persons who receive **the packages** covered by this exemption may **reoffer them** for transportation provided no modifications or changes are made to **the** packages, all terms of this **exemption** are complied with and a current copy **of** this exemption is maintained at each facility **from which** such reoffering occurs.

b. Shippers using the packaging covered by this exemption must comply with all provisions of this exemption, **and all** other applicable requirements **contained** in 49 CFR Parts 171-180.

9. MODES OF TRANSPORTATION AUTHORIZED: Motor vehicle and cargo vessel.

10. MODAL REQUIREMENTS: A copy of **this exemption** must be carried aboard each cargo vessel or motor vehicle used to transport packages covered by this exemption.

11. COMPLIANCE: Failure **by a** person to **comply** with any o'f the following **may** result in suspension **or** revocation'of this exemption and penalties prescribed by the Federal hazardous materials transportation law, 49 U.S.C. Section 5101 **et seq:**

- o All terms and conditions prescribed in **this exemption** and the Hazardous Materials Regulations, 49 CFR Parts 171-180.
- o Registration required by 49 CFR 107.601 **et seq.**, when applicable.

Each "Hazmat employee", as defined in 49 CFR 171.8, who performs a function subject to this exemption **must receive** training on the requirements and conditions of this exemption in addition to the training required by 49 CFR 172.700 through 172.704.

7-05-1998 9:36AM  
JUL-06-1998 09:28

FROM HMT ASSOCIATES LLC 202 463 3512  
RSPA/AAHMS

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Continuation of DOT-E 11930

**Page 4**

No person may use or apply this exemption, including display of its **number**, when the **exemption** has expired or is otherwise no longer, in eff ect.

- 1 2 . **REPORTING REQUIREMENTS:** The carrier is required to report any incident involving loss of packaging contents or packaging failure to the Associate **Administrator** for Hazardous Materials Safety (**AAHMS**) as soon as practicable. (49 **CFR** 171.15 and **171.16** apply to any activity undertaken under the authority of **this** exemption.) In addition, the holder of this exemption must inform the **AAHMS**, in writing, of any incident involving the **package** and shipments made under the terms of this exemption.

Issued at Washington, D.C.:

JUN 5 1998

  
Alan I. Roberts  
**Associate Administrator**  
for Hazardous Materials Safety

(DATE)

Address all inquiries to: Associate Administrator for Hazardous Materials Safety, Research and Special Programs Administration, Department of Transportation, Washington, D.C. 20590.  
Attention: DHM-31.

The original of this exemption is on file at the above office. Photo reproductions and legible reductions of this exemption are permitted. Any alteration of this exemption is prohibited.

Dist: FHWA, USCG  
PO: PTolson

TOTAL P.05

JUN - 3 1998



U.S. Department  
of Transportation  
Research and  
Special Programs  
Administration

600 Pennsylvania Street, S.W.  
Washington, D.C. 20590

APPROVAL CA-9906007

ISSUED BY THE COMPETENT AUTHORITY OF THE UNITED STATES

1. **APPROVAL HOLDER:** Exxon Chemical, Inc.  
P.O. Box 5200  
Baytown, Texas 77252-5200
2. **REGULATORY AUTHORITY:** Paragraph 10.3 of the General Introduction to the International Maritime Dangerous Goods (IMDG) Code.
3. **SYNOPSIS:** Exxon Chemical, Inc. is authorized to ship Pyrophoric solid, inorganic, n.o.s. (contains Aluminum Alkyls), Class 4.2, UN 3200, PG I in the packaging described in paragraph 5(b) below.
4. **BASIS:** This approval is issued in response to a request dated September 30, 1997 and supplemental information dated October 21, 1997 and May 13, 1998, submitted by Mr. Lawrence Blattman on behalf of Exxon Chemical Inc.
5. **PERIOD OF VALIDITY AND CONDITIONS OF APPROVAL:** This approval remains valid until May 15, 2000 or unless terminated by the Associate Administrator for Hazardous Materials Safety. This approval does not provide relief from any requirements of the Hazardous Materials Regulations or the IMDG Code except as expressly stated herein and is subject to the conditions indicated in paragraphs 5, 6 and 7.

(a) **Material Authorized:**

Pyrophoric solid, inorganic, n.o.s. (contains Aluminum Alkyls), Class 4.2, UN 3200, Packing Group I.

(b) **Packaging:**

Packaging prescribed is DOT Specification 51 portable tank which is equivalent to IMO Type 1 portable tank except for the bottom outlet valve. Packaging is approved for transportation by the United States Department of Transportation under exemption DOT-E 11970.

**6. SPECIAL PROVISIONS:**

- (a) All requirements of the United States Department of Transportation exemption DOT-E 11970 must be complied with.
- (b) A copy of this competent authority approval and DOT-E 11970 must accompany the shipment made under the authority of this approval.
- (c) Except for the provisions of this approval, all requirements of the IMDG Code must be met.
- (d) The authority to grant the relief provided within this approval is limited to the extent that the United States government has authority over the transportation of the articles subject to this approval. Transportation in accordance with this approval outside of the United States may require the approval of governments of countries where these articles are so transported.

**7. GENERAL PROVISIONS:**

- (a) Exxon Chemical, Inc. is required to report any incident involving loss of packaging contents or packaging failure to the Associate Administrator for Hazardous Materials Safety (AAHMS) as soon as practicable.
- (b) Exxon Chemical, Inc. is responsible for compliance of this shipment with the terms of this approval. Failure by any person to comply with the terms and conditions of this approval, the Hazardous Materials Regulations, 49 CFR Parts 171-180, or the IMDG Code may result in the suspension or revocation of that person's authority to use this approval. Failure to comply may also subject that person to penalties prescribed by 49 U.S.C. § 5123 and 5124. This approval may be modified, suspended or terminated in its entirety if that action is justified in light of changes in circumstances, including additional information not available when this approval was issued. Unless immediate modification, suspension or termination is necessary to avoid imminent, material harm to person or property, before action is taken, that person will be notified and provided with an opportunity to show why the proposed action should not be taken.
- (c) Each "Hazmat employee," as defined in 49 CFR 171.8 who performs a function subject to this approval must receive training on the requirements and conditions of this approval in addition to the training required by 49 CFR 172.700 through 172.704.

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RESPONSIBLE

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(d) Please refer to the aforementioned approval number in any future correspondence regarding this authorization.

logged at Washington, D.C.

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|DATE|

Alan I. Roberts  
Associate Administrator for  
Hazardous Materials Safety

Address all inquiries to: Associate Administrator for Hazardous Materials Safety, Research and Special Programs Administration, Department of Transportation, Washington, D.C. 20590. Attention: DHM-32



## ASME PRESSURE VESSEL CALCULATIONS

HEBELE JOB# V1099-1 & V1099-2 CALC. REVISION# 0, Dated 2-13-98  
CUSTOMER: ALBEMARLE CORP. CUSTOMER PO# 95000 94546  
DESCRIPTION: 40"00 x 28" S/S VERTICAL TANK

SPECIFICATIONS, DESIGN

AND CALCS. REVIEWED BY: STEVE ROWELL

CHECKED BY: SGD

THESE CALCULATIONS ARE FOR A VESSEL DESIGNED  
USING THE FOLLOWING APPLICABLE CRITERIA (UG-22)

CHECK THE APPLICABLE BOXES

SUPERIMPOSED STATIC REACTIONS FROM WEIGHT OF ATTACHED EQUIPMENT

ATTACHMENT OF:

INTERNALS  STATIC HEAD 4.404 P.S.I.

VESSEL SUPPORTS (i.e.; LUGS, RINGS, SKIRTS, etc.)

CYCLIC AND DYNAMIC REACTIONS DUE TO PRESSURE OR THERMAL VARIATIONS.  
OR FROM EQUIPMENT MOUNTED ON THE VESSEL, AND MECHANICAL LOADINGS.

WIND ASCE-7-95, 110 MPH  INTERNAL PRESSURE 125 PSI

SNOW  EXTERNAL PRESSURE 15 PSI

SEISMIC ZONE  MDMT = -20 °F @ 125 PSIG

IMPACT REACTIONS (i.e.: FLUID SHOCK)

TEMPERATURE GRADIENTS AND DIFFERENTIAL THERMAL EXPANSION

ESTIMATED DRY WEIGHT OF VESSEL 1114 LBS.

ESTIMATED FLOODED / OPERATION WEIGHT OF VESSEL 4828 LBS.

VESSEL EXEMPTION FROM IMPACT TESTING PER:

- UG-20(f)
- UCS-66(a) ...Per Figure UCS-66
- UCS-66(b) ...Per figure UCS-66.1
- UCS-66(c) ...B16.5 Steel Flanges
- UCS-66(d) ...Nuts or .098" Max. Thick
- UCS-66(e) ...S/S
- UNF-65 .....Non Ferrous
- UHA-51(d)

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THIS DRAWING APPROVED FOR FABRICATION  
BY: EPM DATE 2/13/98  
Q.C. Dm DATE 2-13-98  
A.I. BL DATE 2/13/98

HEBELEL VICKSBURG CORP.  
VICKSBURG, MS

Pressure SummaryPressure summary for pressure chamber 1

Identifier	P	T	MAWP	MAP	Pe	UG-99	UCS-66	Corrosion	
	design (psi)	design (deg F)	(psi)	external (psi)	(psi)	I (deg F)	MDMT	Exemption or Stress Reduction	Allowance (in)
TPHEAD	125.0	450.0	169.9	236.9	45.6	1.042		Not applicable	0.062
SHELL1	125.0	450.0	281.0	352.3	15.0	1.042		Not applicable	0.062
CONE	125.0	450.0	125.0	125.0	15.0	1.042		Not applicable	0.062
NOZZLE4	125.0	450.0	5529.0	6836.1	15.0	1.042		Not applicable	0.062
Wind Calculations			125.0		15.0				
N1	125.0	450.0	125.0	125.0	15.0	1.042		Not applicable	0.062
N2	125.0	450.0	125.0	125.0	15.0	1.042		Not applicable	0.062
N3	125.0	450.0	125.0	125.0	15.0	1.042		Not applicable	0.062

Vessel MAWP hot & corroded is 125 psi @ 450 degrees F.

Vessel MAP new & cold is 125 psi @ 70 degrees F.

Vessel allowable external pressure is 15 psi @ 0 degrees F.

Hydrotest pressure calculation based on MAWP

$$\frac{I}{f} = 1.5 * (\text{MAWP} + \text{Operating Liquid Head}) * 1.042 = 195.4 \text{ psi}$$

Vessel hydrotest pressure, horizontal position is ~~195.4~~ psi.

Design notes:

202  2/13/98

Minimum thickness is  $\frac{1}{16}$  inch per UG-16(b).  
Corrosion weight loss is 100% of theoretical loss.

UG-23 stress increase is 1.2.

Test liquid specific gravity is 1.

Minimum nozzle outside projection 0.5 inches.

Maximum stress allowed during field hydrotest is 90% of yield.

Butt weld thickness transitions made by removing material.

P-No 1 material > 1.25 to 1.5 in. chick IS preheated (UCS-56).

Weight Summary

Component .....	Weight (lbs) Contributed by Vessel Elements .....											
	Metal New	Metal Corr	Trays & sup Beds	Packed	Insul	Lining	Piping	Ladder & plat	Rings & Misc	Oper Liquid	Test Liquid	Nozzle & flg
Tphead	199	159	0	0	0	0	0	0	0	743	376	219
Shell1	379	316	0	0	0	0	0	0	0	2462	1223	0
Cone	<b>197</b>	<b>164</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	619	305	0
Nozzle4	2	1	0	0	0	0	0	0	0	0	0	0
	777	640	0	0	0	0	0	0	0	3824	1904	219

Vessel operating weight, corroded: 4.683 lbs

Vessel empty weight, corroded: 859 lbs

Vessel empty weight, new: 996 lbs

Vessel test weight, new: 2,900 lbs

Vessel center of gravity location (from right weld seam)

Vessel lift weight, new: 995 lbs

Center of gravity to seam: 43.9 in

Nozzle Summary

Nozzle mark	OD (in)	tn (in)	Req tn (in)	Al? A2?	Nom t (in)	Req t (in)	User t (in)	Corr (in)	Aa/Ar (%)
N1	9.00	2.5000	0.1857	y    y	0.3125	0.1677		0.0625	764.1
N2	7.50	2.2500	0.1857	y    y	0.3125	0.1677		0.0625	exempt
N3	4.25	1.6250	0.1857	y    y	0.3125	0.1677		0.0625	exempt

m - nozzle thickness

Req tn - nozzle thickness required per UG-45/16

Nom t - vessel wall thickness

Req t - required vessel wall thickness due to pressure + corr per UG-37

User t - local vessel wall thickness (near opening)

Aa - area available per UG-37, governing condition

Ar - area required per UG-37, governing condition

Corr - corrosion allowance on nozzle id.

Nozzle Schedule

Nozzle mark	Service	Size	Materials					
			Nozzle	Impact?	Norm?	Pad	Impact?	Norm?
N1	n1	4.00 10x2.50	SA 240 316	HIGH	n	n		
N2	n2	3.00 IDx2.25	SA 240 316	HIGH	n	n		
N3	n3	1.00 IDx1.62	SA 240 316	HIGH	n	n		

**Thickness Summary**

Component Identifier	Dia (in)	Length (in)	Nom t (in)	Req t (in)	Joint E	Governing Load Status	Deflect Stress (in)
Tthead	40.00 od		0.3125	0.2010	1	internal	
Shell1	40.00 od	28.00	0.3750	0.2166	1	external	0.034
Cone	40.00 od	20.50	0.3750	0.3608	1	wind sh down canpres	0.017
Nozzle4	2.37 od	2.00	0.4360	0.2976	0.85	wind sh down compres	0.000

Nom t - vessel wall thickness

Req t - required vessel thickness due to governing loading + corrosion

E - longitudinal seam joint efficiency

**Load:**

internal - circ stress due to internal pressure governs

external - external pressure governs

wind - combined long stress due to STATUS + wind governs

seismic - combined long stress due to STATUS + seismic governs

TPHEADASME Section VIII Division 1, 1995 Edition. A96 Addenda

Component: 2:1 head  
 Material specification: SA 240 3 16 HIGH

Internal design pressure: P = 125 psi @ 450 deg F  
 External design pressure: Pe = 15 psi @ 0 deg F

Static liquid head: Ps = .758 psi (S.G.= 2, Hs = 10.5 in)

Corrosion allowance: Inner C = 0.0625 Outer= 0 in  
 PWHT is not performed

Radiography: Category A joints - Seamless **NO X-Ray**  
 Head to shell seam - Full UW-II(a) type 2

Estimated weight:  
 capacity: new = 198.8 corr = 159 lb  
 new = 45.1 corr = 45.5 US ga

OD = 40 t = .3125 (nom) flange = 2 forming = .0625 in (new)

Operating liquid: 44.56 US ga, weight: 743.4 lb

Design thickness: (At 450 deg F) Appendix 1-4(c)

$$\begin{aligned} t &= P * D_o * K / (2 * S * E + 2 * P * (K - 0.1)) + \text{Corrosion} + f_a \\ &= 125.758 * 40 * 1 / (2 * 18050 * 1 + 2 * 125.758 * (1 - 0.1)) + 0.0625 + 0.0625 \\ &= 0.2635 \text{ in} \end{aligned}$$

MAP: (New & at 70 deg F) Appendix 1-4(c)

$$\begin{aligned} P &= 2 * S * E * t / (K * D_o - 2 * t * (K - 0.1)) - P_s \\ &= 2 * 18800 * 1 * 0.25 / (1 * 40 - 2 * 0.25 * (1 - 0.1)) - .758 \\ &= 236.9158 \text{ psi} \end{aligned}$$

MAWP: (Corroded & at 450 deg F) Appendix 1-4(c)

$$\begin{aligned} P &= 2 * S * E * t / (K * D_o - 2 * t * (K - 0.1)) - P_s \\ &= 2 * 18050 * 1 * 0.1875 / (1 * 40 - 2 * 0.1875 * (1 - 0.1)) - .758 \\ &= 169.9007 \text{ psi} \end{aligned}$$

External Pressure: (Corroded & at 0 deg F) UG-33(d)

$$\begin{aligned} A &= .125 / (R_o / t) \\ &= .125 / (0.886 * 40 / 0.10523) \\ &= 0.000371 \end{aligned}$$

From table HA-2: B = 5061.8

$$\begin{aligned} P_a &= B / (R_o / t) \\ &= 5061.8 / (0.886 * 40 / 0.10523) \\ &= 15.0297 \text{ psi} \end{aligned}$$

Check the external pressure per UG-33(a)(l)

$$\begin{aligned} t &= 1.67 * P_a * D_o * K / (2 * S * E + 2 * 1.67 * P_a * (K - 0.1)) \\ &= 1.67 * 15.0297 * 40 * 1 / (2 * 18800 * 1 + 2 * 1.67 * 15.0297 * (1 - 0.1)) \\ &= 0.02667 \text{ in} \end{aligned}$$

Design thickness for external pressure Pa = 15.0297 psi:

$$\begin{aligned} &= t + \text{Corrosion} + f_a \\ &= 0.10523 + 0.0625 + 0.0625 \\ &= 0.23023 \text{ in} \end{aligned}$$

Maximum Allowable External Pressure: (Corroded @ 0 deg F)

TPHEAD

$$\begin{aligned} A &= .125/(R_o/t) \\ &= .125/(0.886*40/0.1875) \\ &= 0.000661 \end{aligned}$$

From table HA-2:                  B = 8624.8

$$\begin{aligned} P_a &= B/(R_o/t) \\ &= 8624.8/(0.886*40/0.1875) \\ &= 45.6306 \text{ psi} \end{aligned}$$

Check the Maximum External Pressure: UG-33(a)(1) & ADD. 1-4(c)

$$\begin{aligned} P_e &= 2*S*E*t/((K*D_o - 2*t*(K-0.1))*1.67) \\ &= 2*18800*1*0.1875/((1*40 - 2*0.1875*(1-0.1))*1.67) \\ &= 106.437 \text{ psi} \end{aligned}$$

The maximum allowable external pressure is 45.6306 psi.

UG-32(l) Minimum Straight Flange Thickness

Design thickness: (At 450 deg F)      Appendix 1-1(a)

$$\begin{aligned} t &= P*R_o/(S*E + 0.4*P) + \text{Corrosion} \\ &= 170.5147*20/(18050*1 + 0.4*170.5147) + 0.0625 \\ &= 0.2507 \text{ in} \end{aligned}$$

SHELL1ASME Section VIII Division 1, 1995 Edition, A96 Addenda

Component: Cylinder  
 Material specification: SA 240 3 16 HIGH

Internal design pressure:  $P = 125$  psi @ 450 deg F  
 External design pressure:  $Pe = 15$  psi @ 0 deg F

Static liquid head:  $Ps = 2.779$  psi (S.G. = 2,  $Hs = 38.5$  in)

Corrosion allowance: Inner C = 0.0625 Outer = 0 in

PWHT is not performed

Radiography: Category A joints - Full UW-1 l(a) type I  
 Category B joints - Full UW-1 l(a) type 1

Estimated weight:  
 capacity: new = 379.1 corr = 316.4 lb  
 new = 146.661 corr = 147.597 US ga

Operating liquid: 147.6 US ga, weight: 2462 lb

OD = 40 length Lc = 28 t = 0.375 in (new)

Design thickness: (At 450 deg F) Appendix 1-1(a)

$$\begin{aligned} t &= P * Ro / (S * E + 0.4 * P) + \text{Corrosion} \\ &= 127.779 * 20 / (18050 * 1 + 0.4 * 127.779) + 0.0625 \\ &= 0.2037 \text{ in} \end{aligned}$$

MAP: (New & at 70 deg F) Appendix 1-1(a)

$$\begin{aligned} P &= S * E * t / (Ro - 0.4 * t) - Ps \\ &= 18800 * 1 * 0.375 / (20 - 0.4 * 0.375) - 2.779 \\ &= 352.3847 \text{ psi} \end{aligned}$$

MAWP: (Corroded & at 450 deg F) Appendix 1-1(a)

$$\begin{aligned} P &= S * E * t / (Ro - 0.4 * t) - Ps \\ &= 18050 * 1 * 0.3125 / (20 - 0.4 * 0.3125) - 3.779 \\ &= 28.1026 \text{ psi} \end{aligned}$$

External Pressure: (Corroded & at 0 deg F) UG-28

$$\begin{aligned} L/Do &= 57.9065940 = 1.4477 \quad Do/t = 40/0.1541 = 259.5717 \\ \text{From table G:} \quad A &= 0.000218 \\ \text{From table HA-2:} \quad B &= 2927.3 \end{aligned}$$

$$\begin{aligned} Pa &= 4 * B / (3 * Do/t) \\ &= 4 * 2927.3 / (3 * 40 / 0.1541) \\ &= 15.0366 \text{ psi} \end{aligned}$$

Design thickness for external pressure Pa = 15.0366 psi:

$$\begin{aligned} &= t + \text{Corrosion} \\ &= 0.1541 + 0.0625 \\ &= 0.2166 \text{ in} \end{aligned}$$

Maximum Allowable External Pressure: (Corroded @ 0 deg F)

$$\begin{aligned} L/Do &= 57.90655140 = 1.4477 \quad Do/t = 40/0.3125 = 128 \\ \text{From table G:} \quad A &= 0.000627 \\ \text{From table HA-2:} \quad B &= 8485.7 \end{aligned}$$

$$\begin{aligned} Pa &= 4 * B / (3 * Do/t) \\ &= 4 * 8485.7 / (3 * 40 / 0.3125) \\ &= 88.3927 \text{ psi} \end{aligned}$$

SHELL1Vacuum + external loading check (Bergman, ASME paper 54-A-104)

Calculate the compressive loading due to weight + bending:

$$\begin{aligned} Pv &= W / (\pi * Dm) + 48 * M / (\pi * Dm^2) \\ &= 694 / (\pi * 39.6875) + 48 * 335.4012 / (\pi * 39.6875^2) \\ &= 8.819644 \text{ lb/in} \end{aligned}$$

$$\begin{aligned} \text{Alpha} &= Pv / (Pe * Do) \\ &= 8.819644 \text{ I} (15 * 40) = 0.0147 \end{aligned}$$

From Fig. 1 of the Bergman paper # lobes @ collapse n = 5

$$\begin{aligned} m &= 1.23 / (L/Do)^2 \\ &= 1.23 / (57.90655 / 40)^2 = 0.58691 \end{aligned}$$

$$\begin{aligned} P'o &= Pe * (n^2 - 1 + m + m * \text{Alpha}) / (n^2 - 1 + m) \\ &= 15 * (5^2 - 1 + 0.58691 + 0.58691 * 0.0147) / (5^2 - 1 + 0.58691) \\ &= 15.00526 \text{ psi} \end{aligned}$$

As P'o < Pa (88.3927) interaction stresses are ok.

CONEASME Section VIII Division 1, 1995 Edition, A96 Addenda

Component: Transition  
 Material specification: SA 240 3 16 HIGH

Internal design pressure: P = 125 psi @ 450 deg F  
 External design pressure: Pe= 15 psi @ 0 deg F

Static liquid head: Ps= 2.779 psi (S.G.= 2, Hs= 38.5 in)

Corrosion allowance: Inner C = 0.0625 Outer= 0 in

PWHT is not performed

Radiography: Category A joints - Full UW-I l(a) type 1  
 Category B joints - Full UW-11 (a) type 1

Estimated weight: new = 196.6 corr = 164.5 lb  
 capacity: new = 36.6 corr = 37.1 US ga

Operating liquid: 37.1 US ga, weight: 618.9 lb

Axial Lc = 20.5 big end OD = 40 small end OD = 2.375 in  
 Cone tc = 0.375 in (min)

Design thickness: (At 450 deg F) Appendix 1-4(e)

$$\begin{aligned} t &= P*Do/(2*cos(alpha)*(S*E + 0.4*P)) + \text{Corrosion} \\ &= 127.779*40/(2*cos(42.5421)*(18050*1 + 0.4*127.779)) + 0.0625 \\ &= 0.2541 \text{ in} \end{aligned}$$

MAP: (New & at 70 deg F) Appendix 1-4(e)

$$\begin{aligned} P &= 2*S*E*t*cos(alpha)/(Do - 0.8*t*cos(alpha)) - Ps \\ &= 2*18800*1*0.375*cos(42.5421)/(40 - 0.8*0.375*cos(42.5421)) - 2.779 \\ &= 258.3795 \text{ psi} \end{aligned}$$

MAWP: (Corroded & at 450 deg F) Appendix 1-4(e)

$$\begin{aligned} P &= 2*S*E*t*cos(alpha)/(Do - 0.8*t*cos(alpha)) - Ps \\ &= 2*18050*1*0.3125*cos(42.5421)/(40 - 0.8*0.3125*cos(42.5421)) - 2.779 \\ &= 305.9776 \text{ psi} \end{aligned}$$

$$\begin{aligned} Le &= (L/2)*(1 + Ds/DL) \\ &= (20.5/2)*(1 + 2.375/40) \\ &= 10.85859 \text{ in} \end{aligned}$$

External Pressure: (Corroded & at 0 deg F) UG-33(f)

$$\begin{aligned} te &= t*cos(alpha) = .075999 \\ Le/DL &= 10.85859/40 = .2715 \quad DL/te = 40/0.075999 = 526.3227 \end{aligned}$$

$$\begin{aligned} \text{From table G: } A &= 0.000434 \\ \text{From table HA-2: } B &= 5949.2 \end{aligned}$$

$$\begin{aligned} Pa &= 4*B/(3*DL/te) \\ &= 4*5949.2/(3*40/0.075999) \\ &= 15.0711 \text{ psi} \end{aligned}$$

Design thickness for external pressure Pa = 15.0711 psi:

$$\begin{aligned} &= t + \text{Corrosion} \\ &= 0.10315 + 0.0625 \\ &= 0.16565 \text{ in} \end{aligned}$$

Maximum Allowable External Pressure: (Corroded @ 0 deg F)

$$te = t*cos(alpha) = .230244$$

CONE

$$\frac{L_e}{D_L} = 10.85859/40 = .2715 \quad D_L/t_e = 40/0.230244 = 173.7287$$

From table G:  $A = 0.002503$   
 From table HA-2:  $B = 12202.6$

$$\begin{aligned} Pa &= 4*B/(3*D_L/t_e) \\ &= 4*12202.6/(3*40/0.230244) \\ &= 93.6525 \text{ psi} \end{aligned}$$

Vacuum + external loading check (Bergman, ASME paper 54-A-104)

Calculate the compressive loading due to weight + bending:

$$\begin{aligned} Pv &= W / (\pi * D_m) + 48 * M / (\pi * D_m^2) \\ &= 4672.556 \text{ I} (\pi * 2.0625)^2 + 48 * 766.1966 / (\pi * 2.0625^2) \\ &= 3473.094 \text{ lb/in} \end{aligned}$$

$$\begin{aligned} \text{Alpha} &= Pv / (P_e * D_o) \\ &= 3473.094 / (15 * 2.375) = 97.49037 \end{aligned}$$

From Fig. 1 of the Bergman paper # lobes @ collapse n = 2

$$\begin{aligned} m &= 1.23 / (L / D_o)^2 \\ &= 1.23 / (10.85859 / 2.375)^2 = 0.05884 \end{aligned}$$

$$\begin{aligned} P'_o &= P_e * (n^2 - 1 + m + m * \text{Alpha}) / (n^2 - 1 + m) \\ &= 15 * (2^2 - 1 + 0.05884 + 0.05884 * 97.49037) / (2^2 - 1 + 0.05884) \\ &= 43.12995 \text{ psi} \end{aligned}$$

As  $P'_o < Pa$  (93.6525) interaction stresses are ok.

Juncture discontinuity stresses (Bednar), new condition:Cylinder large end:

Static head of liquid:  $P_h = 2.779 \text{ psi}$   
 Juncture calculated at:  $P = 127.78 \text{ psi}$

Equivalent pressure for longitudinal stress.  $P_e$ :

$$\begin{aligned} l(+) &= 48 * M / (\pi * D^2) - W / (\pi * D) \\ &= 48 * 338.1875 / (\pi * 39.626^2) - 694 / (\pi * 39.626) \\ l(+) &= -2.284 \text{ 1} \end{aligned}$$

$$\begin{aligned} l(-) &= -48 * M / (\pi * D^2) - W / (\pi * D) \\ &= -48 * 338.1875 / (\pi * 39.626^2) - 694 / (\pi * 39.626) \\ l(-) &= -8.865501 \end{aligned}$$

$$\begin{aligned} P_e(+) &= P + 4 * l(+) / D = 127.78 + 4 * -2.2841 / 39.626 \\ &= 127.5494 \end{aligned}$$

$$\begin{aligned} P_e(-) &= P + 4 * l(-) / D = 127.78 + 4 * -8.865501 / 39.626 \\ &= 126.8851 \end{aligned}$$

$$\begin{aligned} \sigma_L &= (P_e * R / t) * (0.5 - X * \text{Sqr}(R / t)) \\ &= (127.5494 * 19.813 / 0.375) * (0.5 - 0.495 * \text{Sqr}(19.813 / 0.375)) \\ &= -20877.72 \text{ psi [longitudinal stress, outside surface]} \end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S = 56400 \text{ psi}$   $\sigma_L$  is acceptable

$$\begin{aligned} \sigma_L &= (P_e * R / t) * (0.5 + X * \text{Sqr}(R / t)) \\ &= (127.5494 * 19.813 / 0.375) * (0.5 + 0.495 * \text{Sqr}(19.813 / 0.375)) \\ &= 27616.75 \text{ psi [longitudinal stress, inside surface]} \end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S * E_c = 56400 \text{ psi}$   $\sigma_L$  is acceptable

CONE

$$\begin{aligned}\sigma_t &= (P_e * R/t) * (1 - (Pe/P) * Y * Sqr(R/t)) \\ &= (127.78 * 19.813 / 0.375) * (1 - (127.5494 / 127.78) * 0.272 * Sqr(19.813 / 0.375)) \\ &= -6572.5 \text{ psi [membrane hoop stress]}\end{aligned}$$

Allowable per 1-5(g)(1),  $\sigma_t = 1.5 * S = 28200$  psi  $\sigma_t$  is acceptable

Cone large end:

$$\begin{aligned}\sigma_L &= (Pe * R/t) * (0.5 / (n * cos(\alpha)) - U * Sqr(R/t)) \\ &= (127.5494 * 19.813 / 0.375) * (0.5 / (1 * cos(42.5421)) - 0.495 * Sqr(19.813 / 0.375)) \\ &= -19673.94 \text{ psi [longitudinal stress, outside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S = 56400$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_L &= (Pe * R/t) * (0.5 / (n * cos(\alpha)) + U * Sqr(R/t)) \\ &= (127.5494 * 19.813 / 0.375) * (0.5 / (1 * cos(42.5421)) + 0.495 * Sqr(19.813 / 0.375)) \\ &= 28820.53 \text{ psi [longitudinal stress, inside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S * E_c = 56400$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_t &= (P_e * R/t) * (1 / (n * cos(\alpha)) - (Pe/P) * Y * Sqr(R/t)) \\ &= (127.78 * 19.813 / 0.375) * (1 / (1 * cos(42.5421)) - (127.5494 / 127.78) * 0.272 * Sqr(19.813 / 0.375)) \\ &= -4160.612 \text{ psi [membrane hoop stress]}\end{aligned}$$

Allowable per 1-5(g)(1),  $\sigma_t = 1.5 * S = 28200$  psi  $\sigma_t$  is acceptable

Cylinder small end:

$$\begin{aligned}\text{Static head of liquid:} \quad Ph &= 4.259 \text{ psi} \\ \text{Juncture calculated at:} \quad P &= 129.26 \text{ psi}\end{aligned}$$

Equivalent pressure for longitudinal stress. Pe:

$$\begin{aligned}l(+) &= 48 * M / (\pi * D^2) - W / (\pi * D) \\ &= 48 * 772.5616 / (\pi * 1.94^2) - 4672.556 / (\pi * 1.94) \\ l(+) &= 2369.664\end{aligned}$$

$$\begin{aligned}l(-) &= -48 * M / (\pi * D^2) - W / (\pi * D) \\ &= -48 * 772.5616 / (\pi * 1.94^2) - 4672.556 / (\pi * 1.94) \\ l(-) &= -3902.984\end{aligned}$$

$$\begin{aligned}Pe(+) &= P + 4 * l(+) / D = 129.26 + 4 * 2369.664 / 1.94 \\ &= 5015.166\end{aligned}$$

$$\begin{aligned}Pe(-) &= P + 4 * l(-) / D = 129.26 + 4 * -3902.984 / 1.94 \\ &= -7918.13\end{aligned}$$

$$\begin{aligned}\sigma_L &= (Pe * R_s / t_s) * (0.5 + X * Sqr(R_s / t_s)) \\ &= (-7918.13 * 0.97 / 0.436) * (0.5 + 0.469 * Sqr(0.97 / 0.436)) \\ &= -2113 1.21 \text{ psi [longitudinal stress, outside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S = 56400$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_L &= (Pe * R_s / t_s) * (0.5 - X * Sqr(R_s / t_s)) \\ &= (-7918.13 * 0.97 / 0.436) * (0.5 - 0.469 * Sqr(0.97 / 0.436)) \\ &= 35 15.185 \text{ psi [longitudinal stress, inside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S * E_c = 39480$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_t &= (P * R_s / t_s) * (1 + (Pe/P) * Y * Sqr(R_s / t_s)) \\ &= (129.26 * 0.97 / 0.436) * (1 + (-7918.13 / 129.26) * 0.309 * Sqr(0.97 / 0.436)) \\ &= -783 1.547 \text{ psi [membrane hoop stress]}\end{aligned}$$

CONE

Allowable per 1-5(g)(1),  $\sigma_t = 1.5 * S = 28200$  psi  $\sigma_t$  is acceptable

Cone small end:

$$\begin{aligned}\sigma_L &= (P_e * R_s / t_s) * (0.5 / (n * \cos(\alpha)) + U * \sqrt{R_s / t_s}) \\ &= (-7918.13 * 0.97 / 0.436) * (0.5 / (0.86 * \cos(42.5421)) + 0.634 * \sqrt{0.97 / 0.436}) \\ &= -30559.49 \text{ psi [longitudinal stress, outside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S = 56400$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_L &= (P_e * R_s / t_s) * (0.5 / (n * \cos(\alpha)) - U * \sqrt{R_s / t_s}) \\ &= (-7918.13 * 0.97 / 0.436) * (0.5 / (0.86 * \cos(42.5421)) - 0.634 * \sqrt{0.97 / 0.436}) \\ &= 2757.812 \text{ psi [longitudinal stress, inside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 3 * S * E_c = 39480$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_t &= (P * R_s / t_s) * (1 / (n * \cos(\alpha)) + (P_e / P) * Y * \sqrt{R_s / t_s}) \\ &= (129.26 * 0.97 / 0.436) * (1 / (0.86 * \cos(42.5421)) + (-7918.13 / 129.26) * 0.309 * \sqrt{0.97 / 0.436}) \\ &= -7665.271 \text{ psi [membrane hoop stress]}\end{aligned}$$

Allowable per 1-S(g)(1),  $\sigma_t = 1.5 * S = 28200$  psi  $\sigma_t$  is acceptable

Juncture discontinuity stresses (Bednar), corroded condition:Cylinder large end:

Static head of liquid:  $P_h = 2.779$  psi  
Juncture calculated at:  $P = 127.78$  psi

Equivalent pressure for longitudinal stress,  $P_e$ :

$$\begin{aligned}I(+) &= 48 * M / (\pi * D^2) - W / (\pi * D) \\ &= 48 * 338.1875 / (\pi * 39.688^2) - 694 / (\pi * 39.688) \\ I(+) &= -2.285664\end{aligned}$$

$$\begin{aligned}I(-) &= -48 * M / (\pi * D^2) - W / (\pi * D) \\ &= -48 * 338.1875 / (\pi * 39.688^2) - 694 / (\pi * 39.688) \\ I(-) &= -8.846519\end{aligned}$$

$$\begin{aligned}P_e(+) &= P + 4 * I(+) / D = 127.78 + 4 * -2.285664 / 39.688 \\ &= 127.5496\end{aligned}$$

$$\begin{aligned}P_e(-) &= P + 4 * I(-) / D = 127.78 + 4 * -8.846519 / 39.688 \\ &= 126.8884\end{aligned}$$

$$\begin{aligned}\sigma_L &= (P_e * R / t) * (0.5 - X * \sqrt{R / t}) \\ &= (127.5496 * 19.844 / 0.3125) * (0.5 - 0.495 * \sqrt{19.844 / 0.3125}) \\ &= -27898.95 \text{ psi [longitudinal stress, outside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S = 39710$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_L &= (P_e * R / t) * (0.5 + X * \sqrt{R / t}) \\ &= (127.5496 * 19.844 / 0.3125) * (0.5 + 0.495 * \sqrt{19.844 / 0.3125}) \\ &= 35998.45 \text{ psi [longitudinal stress, inside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S * E_c = 39710$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_t &= (P * R / t) * (1 - (P_e / P) * Y * \sqrt{R / t}) \\ &= (127.78 * 19.844 / 0.3125) * (1 - (127.5496 / 127.78) * 0.272 * \sqrt{19.844 / 0.3125}) \\ &= -9441.52 \text{ psi [membrane hoop stress]}\end{aligned}$$

Allowable per 1-j(g)(1),  $\sigma_t = 1.5 * S = 27075$  psi  $\sigma_t$  is acceptable

CONECone large end:

$$\begin{aligned}\sigma_L &= (Pe * R/t) * (0.5 / (n * \cos(\alpha)) - U * \text{Sqr}(R/t)) \\ &= (127.5496 * 19.844 / 0.3125) * (0.5 / (1 * \cos(42.5421)) - \\ &\quad 0.495 * \text{Sqr}(19.844 / 0.3125)) \\ &= -26452.16 \text{ psi [longitudinal stress, outside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S = 39710$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_L &= (Pe * R/t) * (0.5 / (n * \cos(\alpha)) + U * \text{Sqr}(R/t)) \\ &= (127.5496 * 19.844 / 0.3125) * (0.5 / (1 * \cos(42.5421)) + \\ &\quad 0.495 * \text{Sqr}(19.844 / 0.3125)) \\ &= 37445.25 \text{ psi [longitudinal stress, inside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S * E_c = 39710$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_t &= (P * R/t) * (1 / (n * \cos(\alpha)) - (Pe / P) * Y * \text{Sqr}(R/t)) \\ &= (127.78 * 19.844 / 0.3125) * (1 / (1 * \cos(42.5421)) - \\ &\quad (127.5496 / 127.78) * 0.272 * \text{Sqr}(19.844 / 0.3125)) \\ &= -6542.703 \text{ psi [membrane hoop stress]}\end{aligned}$$

Allowable per 1-5(g)(1),  $\sigma_t = 1.5 * S = 27075$  psi  $\sigma_t$  is acceptable

Cylinder small end:

$$\begin{aligned}\text{Static head of liquid:} & \quad Ph = 4.259 \text{ psi} \\ \text{Juncture calculated at:} & \quad P = 129.26 \text{ psi}\end{aligned}$$

Equivalent pressure for longitudinal stress, Pe:

$$\begin{aligned}I(+) &= 48 * M / (\pi * D^2) - W / (\pi * D) \\ &= 48 * 772.5616 / (\pi * 2.002^2) - 4672.556 / (\pi * 2.002) \\ I(+) &= 2202.157\end{aligned}$$

$$\begin{aligned}I(-) &= -48 * M / (\pi * D^2) - W / (\pi * D) \\ &= -48 * 772.5616 / (\pi * 2.002^2) - 4672.556 / (\pi * 2.002) \\ I(-) &= -3687.992\end{aligned}$$

$$\begin{aligned}Pe(+) &= P + 4 * I(+) / D = 129.26 + 4 * 2202.157 / 2.002 \\ &= 4529.173\end{aligned}$$

$$\begin{aligned}Pe(-) &= P + 4 * I(-) / D = 129.26 + 4 * -3687.992 / 2.002 \\ &= -7239.354\end{aligned}$$

$$\begin{aligned}\sigma_L &= (Pe * R_s / t_s) * (0.5 + X * \text{Sqr}(R_s / t_s)) \\ &= (-7239.354 * 1.001 / 0.3735) * (0.5 + 0.464 * \text{Sqr}(1.001 / 0.3735)) \\ &= -24438.74 \text{ psi [longitudinal stress, outside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S = 39710$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_L &= (Pe * R_s / t_s) * (0.5 - X * \text{Sqr}(R_s / t_s)) \\ &= (-7239.354 * 1.001 / 0.3735) * (0.5 - 0.464 * \text{Sqr}(1.001 / 0.3735)) \\ &= 5036.884 \text{ psi [longitudinal stress, inside surface]}\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S * E_c = 27797$  psi  $\sigma_L$  is acceptable

$$\begin{aligned}at &= (P * R_s / t_s) * (1 + (Pe / P) * Y * \text{Sqr}(R_s / t_s)) \\ &= (129.26 * 1.001 / 0.3735) * (1 + (-7239.354 / 129.26) * 0.316 * \text{Sqr}(1.001 / 0.3735)) \\ &= -9690.537 \text{ psi [membrane hoop stress]}\end{aligned}$$

Allowable per 1-5(g)(1),  $\sigma_t = 1.5 * S = 27075$  psi  $\sigma_t$  is acceptable

Cone small end:

CONE

$$\begin{aligned}\sigma_L &= (P_e * R_s / t_s) * (0.5 / (n * \cos(\alpha)) + U * \sqrt{R_s / t_s}) \\ &= (-7239.354 * 1.001 / 0.3735) * (0.5 / (0.837 * \cos(42.5421))) + \\ &\quad 0.662 * \sqrt{1.001 / 0.3735}) \\ &= -36757.55 \text{ psi} [\text{longitudinal stress, outside surface}]\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S = 39710 \text{ psi}$   $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_L &= (P_e * R_s / t_s) * (0.5 / (n * \cos(\alpha)) - U * \sqrt{R_s / t_s}) \\ &= (-7239.354 * 1.001 / 0.3735) * (0.5 / (0.837 * \cos(42.5421))) - \\ &\quad 0.662 * \sqrt{1.001 / 0.3735}) \\ &= 5296.045 \text{ psi} [\text{longitudinal stress, inside surface}]\end{aligned}$$

Allowable per 1-5(g)(2) (yield limits),  $\sigma_L = 2.2 * S * E_c = 27797 \text{ psi}$   $\sigma_L$  is acceptable

$$\begin{aligned}\sigma_t &= (P_e * R_s / t_s) * (1 / (n * \cos(\alpha)) + (P_e / P) * Y * \sqrt{R_s / t_s}) \\ &= (129.26 * 1.001 / 0.3735) * (1 / (0.837 * \cos(42.5421))) + \\ &\quad (-7239.354 / 129.26) * 0.316 * \sqrt{1.001 / 0.3735}) \\ &= -9475.21 \text{ psi} [\text{membrane hoop stress}]\end{aligned}$$

Allowable per 1-5(g)(1),  $\sigma_t = 1.5 * S = 27075 \text{ psi}$   $\sigma_t$  is acceptable

Pe check of the cone large end per Appendix I-8

Total pressure on juncture:	$P = 15 \text{ psi}$
Modulus of elasticity, cylinder:	$E_s = 28100000 \text{ psi}$
Modulus of elasticity, cone:	$E_c = 28100000 \text{ psi}$
Allowable stress, cylinder:	$S_s = 18800 \text{ psi}$
Allowable stress, cone:	$S_c = 18800 \text{ psi}$
Joint efficiency, cylinder:	$E_1 = 1$
Joint efficiency, cone:	$E_2 = 1$
Cylinder thickness:	$t_s = 0.3125 \text{ in}$
Cone thickness:	$t_c = 0.3125 \text{ in}$
Cylinder required thickness:	$t = 0.1541 \text{ in}$
Cone required thickness:	$t_r = 0.10315 \text{ in}$
Outside radius, cylinder:	$R_L = 20 \text{ in}$
Weight acting on large end:	$W_l = 694 \text{ lb}$
Moment acting on large end:	$M_l = 338.1875 \text{ lb-ft}$

Check if U-2(g) calculation is required

$$\begin{aligned}f_{lt} &= -W_l / (\pi * 2 * R_L) + 12 * M_l / (\pi * R_L^2) \\ &= -694 / (\pi * 2 * 20) + 12 * 338.1875 / (\pi * 20^2) \\ &= -2.293224 \text{ lb/in}\end{aligned}$$

$$P * R_L / 2 = 150$$

As  $f_{lt} \leq P * R_L / 2$  a U-2(g) calculation IS NOT required.

$$P / (S_s * E_1) = 15 / (18800 * 1) = 7.978723E-04$$

From table I-8.1 delta = 1.99 degrees

AS delta is less than alpha an area check is required.

$$\begin{aligned}f_l &= W_l / (\pi * 2 * R_L) + 12 * M_l / (\pi * R_L^2) \\ &= 694 / (\pi * 2 * 20) + 12 * 338.1875 / (\pi * 20^2) \\ &= 8.752129 \text{ lb/in}\end{aligned}$$

$$\begin{aligned}Q_L &= P * R_L / 2 + t - 1 \\ &= 15 * 20 / 2 + 8.752129 \\ &= 158.7521 \text{ lb/in}\end{aligned}$$

$$\begin{aligned}A_r L &= (k * Q_L * R_L * \tan(\alpha) / (S_s * E_1)) * (1 - .25 * ((P * R_L - Q_L) / Q_L) * \delta / \alpha) \\ &= (1 * 158.7521 * 20 * \tan(42.542) / (18800 * 1)) * (1 - \\ &\quad .25 * ((15 * 20 - 158.7521) / 158.7521) * 1.99 / 42.542) \\ &= .1534 \text{ in}^2\end{aligned}$$

CONE

$$\begin{aligned} AeL &= .55 * \text{Sqr}(DL * ts) * (ts + tc / \text{Cos}(\alpha)) \\ &= .55 * \text{Sqr}(40 * 0.3125) * (0.3125 + 0.3125 / \text{Cos}(42.542)) \\ &= 1.4324 \text{ in}^2 \end{aligned}$$

AeL >= ArL so no additional area is required per App. 1-8

Pe check of the cone small end per Appendix 1-8

Total pressure on juncture:	P = 15 psi
Modulus of elasticity, cylinder:	Es = 28100000 psi
Modulus of elasticity, cone:	Ec = 28100000 psi
Allowable stress, cylinder:	Ss = 18800 psi
Allowable stress, cone:	Sc = 18800 psi
Joint efficiency, cylinder:	E1 = 1
Joint efficiency, cone:	E2 = 1
Cylinder thickness:	ts = 0.3735 in
Cone thickness:	tc = 0.3125 in
Cylinder required thickness:	t = 0.02164 in
Cone required thickness:	tr = 0.02019 in
Outside radius, cylinder:	Rs = 1.1875 in
Weight acting on small end:	Ws = 4672.556 lb
Moment acting on small end:	Ms = 772.5616 lb-ft

Check if U-2(g) calculation is required

$$\begin{aligned} f2t &= -Ws/(\pi * 2 * Rs) + 12 * Ms/(\pi * Rs^2) \\ &= -4672.556/(\pi * 2 * 1.1875) + 12 * 772.5616/(\pi * 1.1875^2) \\ &= 1466.413 \text{ lb/in} \end{aligned}$$

$$P * Rs/2 = 8.90625$$

As f2t > P \* Rs/2 a U-2(g) calculation IS required.

$$\begin{aligned} f2 &= Ws/(\pi * 2 * Rs) + 12 * Ms/(\pi * Rs^2) \\ &= 4672.556/(\pi * 2 * 1.1875) + 12 * 772.5616/(\pi * 1.1875^2) \\ &= 2718.893 \text{ lb/in} \end{aligned}$$

$$\begin{aligned} Qs &= P * Rs/2 + f2 \\ &= 15 * 1.1875/2 + 2718.893 \\ &= 2727.8 \text{ lb/in} \end{aligned}$$

$$\begin{aligned} ArS &= k * Qs * Rs * \tan(\alpha) / (Ss * E1) \\ &= 1 * 2727.8 * 1.1875 * \tan(42.542) / (18800 * 1) \\ &= .1581 \text{ in}^2 \end{aligned}$$

$$\begin{aligned} AeS &= .55 * \text{Sqr}(Ds * ts) * ((ts - t) + (tc - tr) / \text{Cos}(\alpha)) \\ &= .55 * \text{Sqr}(2.375 * 0.3735) * ((0.3735 - 0.02164) + (0.3125 - 0.02019) / \text{Cos}(42.542)) \\ &= .3878 \text{ in}^2 \end{aligned}$$

AeS >= ArS so no additional area is required per App. 1-8

NOZZLE4ASME Section VIII Division 1, 1995 Edition, A96 Addenda

Component: Cylinder  
 Material specification: SA 182 F316 HIGH <=5"

Internal design pressure: P = 125 psi @ 450 deg F  
 External design pressure: Pe = 15 psi @ 0 deg F

Static liquid head: Ps = 4.404 psi (S.G. = 2, Hs = 61 in)

Corrosion allowance: Inner C = 0.0625 Outer = 0 in

PWHT is not performed

Radiography: Category A joints - Seamless NO X-Ray  
 Category B joints - None UW-11 (c) type 1

Estimated weight: new = 1.5 corr = 1.4 lb  
 capacity: new = .015 corr = .018 US ga

Operating liquid: 0.02 US ga, weight: 0.3 lb

OD = 2.375 length Lc = 2 t = 0.436 in (new)

Design thickness - APP. 1-2(a)(1) 450 deg F

$$\begin{aligned} Z &= (S*E + P)/(S*E - P) \\ &= (18050*0.85 + 129.404)/(18050*0.85 - 129.404) \\ &= 1.017012 \end{aligned}$$

$$\begin{aligned} t &= Ri*(Sqr(Z) - 1) + Corrosion \\ &= 0.814*(Sqr(1.017012) - 1) + 0.0625 \\ &= 0.0694 \text{ in} \end{aligned}$$

MAP (New & at 70) deg F - APP 1-2(a)(1)

$$\begin{aligned} Z &= ((Ri + t) / Ri)^2 \\ &= ((0.7515 + 0.436) / 0.7515)^2 \\ &= 2.496947 \end{aligned}$$

$$\begin{aligned} P &= S*E*(Z - 1)/(Z + I) * Ps \\ &= 18800*0.85*(2.496947 - 1)/(2.496947 + 1) * 4.404 \\ &= 6836.194 \text{ psi} \end{aligned}$$

MAWP (Corroded & at 450) deg F - APP 1-2(a)(1)

$$\begin{aligned} Z &= ((Ri + t) / Ri)^2 \\ &= ((0.814 + 0.3735) / 0.814)^2 \\ &= 2.128229 \end{aligned}$$

$$\begin{aligned} P &= S*E*(Z - 1)/(Z + I) * Ps \\ &= 18050*0.85*(2.128229 - 1)/(2.128229 + 1) * 4.404 \\ &= 5529.033 \text{ psi} \end{aligned}$$

External Pressure: (Corroded & at 0 deg F) UG28

$$\begin{aligned} L/Do &= 57.90655/2.375 = 24.3817 \quad Do/t = 2.375/0.02164 = 109.7505 \\ \text{From table G:} \quad A &= 0.000095 \\ \text{From table HA-2:} \quad B &= 1244.3 \end{aligned}$$

$$\begin{aligned} Pa &= 4*B/(3*Do/t) \\ &= 4*1244.3/(3*2.375/0.02164) \\ &= 15.1167 \text{ psi} \end{aligned}$$

Design thickness for external pressure Pa = 15.1167 psi:

$$\begin{aligned} &= t + Corrosion \\ &= 0.02164 + 0.0625 \end{aligned}$$

NOZZLE4

= 0.08414 in

Maximum Allowable External Pressure: (Corroded @ 0 deg F)

$$\begin{aligned} L/D_o &= 57.90655/2.375 = 24.3817 \quad D_o/t = 2.375/0.3735 = 6.3588 \\ \text{From table G:} \quad A &= 0.028786 \\ \text{From table HA-2:} \quad B &= 14875.8 \end{aligned}$$

$$\begin{aligned} P_{al} &= (2.167/(D_o/t) - .0833)*B \\ &= (2.167/(2.375/0.3735) - .0833)*14875.8 \\ &= 3830.359 \text{ psi} \end{aligned}$$

$$\begin{aligned} P_{a2} &= 2*Sy/(D_o/t)*(1 - 1/(D_o/t)) \\ &= 2*14040/(2.375/0.3735)*(1 - 1/(2.375/0.3735)) \\ &= 3721.483 \text{ psi} \end{aligned}$$

Allowable external pressure = lesser of Pal or Pa2  
 = 3721.483 psi

Vacuum + external loading check (Bergman, ASME paper 54-A-104)

Calculate the compressive loading due to weight + bending:

$$\begin{aligned} P_v &= W / (\pi * D_m) + 48 * M / (\pi * D_m^2) \\ &= 4673.956 / (\pi * 2.0015) + 48 * 811.8597 / (\pi * 2.0015^2) \\ &= 3839.754 \text{ lb/in} \end{aligned}$$

$$\begin{aligned} \text{Alpha} &= P_v / (P_e * D_o) \\ &= 3839.754 / (15 * 2.375) = 107.7826 \end{aligned}$$

From Fig. 1 of the Bergman paper # lobes @ collapse n = 2

$$\begin{aligned} m &= 1.23 / (L / D_o)^2 \\ &= 1.23 / (57.90655 / 2.375)^2 = 0.00207 \end{aligned}$$

$$\begin{aligned} P'_o &= P_e * (n^2 - 1 + m + m * \text{Alpha}) / (n^2 - 1 + m) \\ &= 15 * (2^2 - 1 + 0.00207 + 0.00207 * 107.7826) / (2^2 - 1 + 0.00207) \\ &= 16.11478 \text{ psi} \end{aligned}$$

As P'\_o < Pa (3721.383) interaction stresses are ok.

CONTENTS

Liquid level from datum: 61 in  
Liquid specific gravity: 2

Liquid acts vertically

Wind Calculations

Method of wind analysis:	ASCE 7-95
Elevation of base above grade:	Oft
Increase effective outer diameter:	Oft
Wind force coefficient Cf:	0.7
Basic wind speed, V:	110 mph
Importance factor, I:	I
Exposure category:	C

Period of vibration calculation

The fundamental period of vibration is **calculated** using the **Rayleigh** method of approximation by the numerical integration of the following formulae:

$$T = 2 * \pi * \text{Sqr} [ \text{Sum } W^*y^*2 / g(\text{Sum } W^*y) ]$$

T(operating)	= .22 seconds
T(vacuum)	= .212 seconds
T(empty)	= .09 seconds
T(test, new)	= .16 seconds

Gust Effect Factor, vacuum condition (ASCE 6.6 Category III)

$$\begin{aligned} Iz^- &= c * (33/z^-)^{(1/6)} \\ &= 0.2 * (33/15)^{(1/6)} \\ &= .228087 \end{aligned}$$

$$\begin{aligned} Lz^- &= l * (z^-/33)^{\epsilon_p} \\ &= 500 * (15/33)^0.2 \\ &= 427.0566 \end{aligned}$$

$$\begin{aligned} Q-2 &= 1 / (1 + 0.63 * ((b + h) / Lz^-)^{0.63}) \\ &= 1 / (1 + 0.63 * ((0.1979167 + 5.029533) / 427.0566)^{0.63}) \\ &= .9621639 \end{aligned}$$

$$\begin{aligned} Vz^- &= b^- * (z^-/33)^{\alpha^-} * V_{ref} \\ &= 0.65 * (15/33)^0.1538462 * 161.3333 \\ &= 92.88744 \end{aligned}$$

$$\begin{aligned} N1 &= n1 * Lz^- / Vz^- \\ &= 4.717 * 427.0566 / 92.88744 \\ &= 21.68674 \end{aligned}$$

$$\begin{aligned} Rn &= 7.465 * N1 / ((1 + 10.302 * N1)^{(5/3)}) \\ &= 7.465 * 21.68674 / ((1 + 10.302 * 21.68674)^{(5/3)}) \\ &= 1.953433E-02 \end{aligned}$$

$$\begin{aligned} Rh &= 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ &= 1/1.174882 - (1/(2*1.174882^2)) * (1 - e^{(-2*1.174882)}) \\ &= .5234751 \end{aligned}$$

$$\begin{aligned} Rb &= 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ &= 1/4.623268E-02 - (1/(2*4.623268E-02^2)) * (1 - e^{(-2*4.623268E-02)}) \\ &= .9698777 \end{aligned}$$

$$\begin{aligned} Rd &= 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ &= 1/0.154779 - (1/(2*0.154779^2)) * (1 - e^{(-2*0.154779)}) \\ &= .9043295 \end{aligned}$$

$$\begin{aligned} R^2 &= (1/beta) * Rn * Rh * Rb * (0.53 + .47 * Rd) \\ &= (1/0.025) * 1.953433E-02 * 0.5234751 * 0.9698777 * (0.53 + .47 * 0.9043295) \\ &= .3788705 \end{aligned}$$

$$\begin{aligned} G &= (1 + 2*g*Iz^- * \text{Sqr}(Q^2 + R^2)) / (1 + 7*Iz^-) \\ &= (1 + 2*3.5*0.228087 * \text{Sqr}(0.9621639 + 0.3788705)) / (1 + 7*0.228087) \\ &= 1.09717 \end{aligned}$$

Wind CalculationsVelocity Pressure Coefficients, Kz and qz

Height (ft)	Z	Kz	qz =
			0.00256*Kz*Kzt*V^2*I
15.0	0.85		26.32

Design Wind Force determined from:  $F = qz * Gf * Cf * Af$

Stresses due to Wind + External pressure, Corroded

Elevation above base (in.)	Type	Minimum thickness (in.)	Circ joint E	Required thickness1	Overhead weight (lbs)	Bending moment (lb-ft)
22.50	cyl	0.3125	1.00	0.0111	694.0	335.4
2.00	trans	0.3125	1.00	0.2664	4672.51	766.1
0.00	cyl	0.3735	0.70	0.2120	4673.91	811.8

Table Continues	Maximum tensile stress/E (psi)	Allowable tensile stress (psi)	Maximum compressive stress  E=1 (psi)	Allowable compressive stress (psi)	Vacuum
	-476.9	18800.0*1.2	497.7	11649.3*1.2	15.0
	8797.8	18800.0*1.2	15084.4	14744.8*1.2	15.0
	8981.1	18800.0*1.2	10293.8	15116.0*1.2	15.0
	-	-	-	-	-

Gust Effect Factor, operating condition (ASCE 6.6 Category III)

$$\begin{aligned} I_z^- &= c * (33/z^-)^(1/6) \\ &= 0.2 * (33/15)^(1/6) \\ &= .228087 \end{aligned}$$

$$\begin{aligned} L_z^- &= I * (z^-/33)^{\alpha_p} \\ &= 500 * (15/33)^{0.2} \\ &= 427.0566 \end{aligned}$$

$$\begin{aligned} Q-2 &= 1 / (1 + 0.63 * ((b + h) / L_z^-)^{0.63}) \\ &= 1 / (1 + 0.63 * ((0.1979167 + 5.029533) / 427.0566)^{0.63}) \\ &= .9621639 \end{aligned}$$

$$\begin{aligned} V_z^- &= b^- * (z^-/33)^{\alpha_v} * V_{ref} \\ &= 0.65 * (15/33)^{0.1538462} * 161.3333 \\ &= 92.88744 \end{aligned}$$

$$\begin{aligned} N_1 &= n_l * L_z^- / V_z^- \\ &= 4.5455 * 427.0566 / 92.88744 \\ &= 20.89826 \end{aligned}$$

$$\begin{aligned} R_n &= 7.465 * N_1 / ((1 + 10.302 * N_1)^{(5/3)}) \\ &= 7.465 * 20.89826 / ((1 + 10.302 * 20.89826)^{(5/3)}) \\ &= 2.001703E-02 \end{aligned}$$

$$\begin{aligned} R_h &= 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ &= 1/1.132166 - (1/(2*1.132166^2)) * (1 - e^{(-2*1.132166)}) \\ &= .5337149 \end{aligned}$$

$$R_b = 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)})$$

Wind Calculations

$$= 1/4.455176E-02 - (1/(2*4.455176E-02^2))*(1 - e^{(-2*4.455176E-02)}) \\ = .9709488$$

$$Rd = 1/n - (1/(2*n^2))*(1 - e^{(-2*n)}) \\ = 1/0.1491515 - (1/(2*0.1491515^2))*(1 - e^{(-2*0.1491515)}) \\ = .9075597$$

$$R^2 = (1/beta)*Rn*Rh*Rb*(0.53 + .47*Rd) \\ = (1/0.024)*2.001703E-02*0.5337149*0.9709488*(0.53 + .47*0.9075597) \\ = .4134311$$

$$G = (1 + 2*g*Iz^-*Sqr(Q^2 + R^2))/(1 + 7*Iz^-) \\ = (1 + 2*3.5*0.228087*Sqr(0.9621639 + 0.4134311))/(1 + 7*0.228087) \\ = 1.106287$$

Velocity Pressure Coefficients, Kz and qz

Height	Z	Kz	qz =
(ft)			0.00256*Kz*Kzt*V^2*I
15.0	0.85	26.32	

Design Wind Force determined from:  $F = qz * Gf * Cf * Af$

Stresses due to Wind + pressure, Operative & Corroded

Elevation	Type	Minimum Circ	Required	Overhead	Bending
(above base)		thickness	joint thickness	weight	manent
I	-	-	-	-	-
22.50	cyl	0.3125	1.00	0.0566	694.01
2.00	trans	<b>0.3125</b>	<b>1.00</b>	<b>0.2983</b>	4672.5
3.00	cyl	0.3735	0.70	0.2351	4673.91

Table Continues	Maximum	Allowable	Maximum	Allowable	
	tensile stress/E	tensile stress	compressive stress	compressive stress	(Pressure)
	(psi)	(psi)	E=1 (psi)	(psi)	(psi)
	-	-	-	-	-
	3905.1	18050.0*1.2	28.3	10129.5*1.2	125.0
	9107.2	18050.0*1.2	15183.7	13255.3*1.2	125.0
	<b>9257.4</b>	18050.0*1.2	<b>10349.3</b>	13697.2*1.2	<b>125.0</b>
	-	-	-	-	-

Wind deflection report, operating & corroded

Elevation	Elastic Modulus	Inertia	Platform Total wind	Bending	Deflection
start	Modulus		wind & other	(platform [section top])	
I	-	-	-	-	-
22.50	26.1	<b>0.369</b>	0.0	<b>214.4</b>	0.0
		0.053	0.0	275.9	0.0
		0.000	0.0	276.5	0.0
		-	-	-	-

Gust Effect Factor, empty condition (ASCE 6.6 Category III)

$$Iz^- = c * (33/z^-)^{1/6}$$

Wind Calculations

$$= 0.2 * (33/15)^{(1/6)} \\ = .228087$$

$$Lz^- = I * (z^-/33)^{ep} \\ = 500 * (15/33)^{0.2} \\ = 427.0566$$

$$Q-2 = 1 / (1 + 0.63 * ((b + h) / Lz^-)^{0.63}) \\ = 1 / (1 + 0.63 * ((0.1979167 + 5.029533) / 427.0566)^{0.63}) \\ = .9621639$$

$$Vz^- = b^- * (z^-/33)^{a^-} * Vref \\ = 0.65 * (15/33)^{0.1538462} * 161.3333 \\ = 92.88744$$

$$N1 = nl * Lz^- / Vz^- \\ = 11.1111 * 427.0566 / 92.88744 \\ = 51.08408$$

$$Rn = 7.465 * N1 / ((1 + 10.302 * N1)^{(5/3)}) \\ = 7.465 * 51.08408 / ((1 + 10.302 * 51.08408)^{(5/3)}) \\ = 1.108144E-02$$

$$Rh = 1/n * (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ = 112.767487 * (1/(2*2.767487^2)) * (1 - e^{(-2*2.767487)}) \\ = .2963135$$

$$Rb = 1/n * (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ = 1/0.1089031 * (1/(2*0.1089031^2)) * (1 - e^{(-2*0.1089031)}) \\ = .9311851$$

$$Rd = 1/n * (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ = 1/0.3645886 * (1/(2*0.3645886^2)) * (1 - e^{(-2*0.3645886)}) \\ = .7954978$$

$$R^2 = (1/beta) * Rn * Rh * Rb * (0.53 + .47 * Rd) \\ = (1/0.02) * 1.108144E-02 * 0.2963135 * 0.9311851 * (0.53 + .47 * 0.7954978) \\ = .1381867$$

$$G = (I + 2*g*Iz^- * Sqr(Q^2 + R^2)) / (1 + 7*Iz^-) \\ = (1 + 2*3.5*0.228087 * Sqr(0.9621639 + 0.1381867)) / (1 + 7*0.228087) \\ = 1.030115$$

Velocity Pressure Coefficients, Kz and qz

Height (ft)	Z	Kz	qz	=	0.00256*Kz*Kzt*V^2*I
15.0	0.85	26.32			

Design Wind Force determined from:  $F = qz * Gf * Cf * Af$

Stresses due to Wind, Empty & Corroded

Elevation above base (in.)	Type	Minimum thickness (in.)	Circ joint (in.)	Required thickness (in.)	Overhead weight (lbs)	Bending moment (lb-ft)
22.50	cyl	0.3125	1.00	0.0006	694.0	314.8
2.00	trans	0.3125	1.00	0.2082	848.2	719.21
0.00	cyl	0.3738	0.70	0.1755	849.6	762.11

Wind Calculations

Table Continues	Maximum	Allowable	Maximum	Allowable	(Pressure (psi))
	tensile stress/E (psi)	tensile stress (psi)	compress) E-1 (psi)	compressive stress (psi)	
I	-8.0	18800.0*1.2	27.5	11649.3*1.2	0.0
	10651.5	18800.0*1.2	11788.7	14744.8*1.2	0.0
	10600.8	18800.0*1.2	8144.1	15116.0*1.2	0.0
	-	-	-	-	-

Wind deflection report, empty & corroded

Elevation	Elastic Modulus	Inertia	Platform wind	Total wind	Bending	Deflection
start	Modulus		wind	& other	(platform	section top
above base			shear	shear	& other)	
(in.)	(psi x10^6)(I. ft^4)		(lbs)	(lbs)	(lb-ft)	(in.)
22.50	28.1	0.369	0.0	199.6	0.0	0.0299
			0.0	256.8	0.0	0.0152
2.00 0.00	28.1 28.1	0.053 0.000	0.0	257.5	0.0	0.0005
-	-	-	-	-	-	-

Gust Effect Factor, test condition (ASCE 6.6 Category III)

$$\begin{aligned} I_{z^-} &= c * (33/z^-)^{(1/6)} \\ &= 0.2 * (33/15)^{(1/6)} \\ &= .228087 \end{aligned}$$

$$\begin{aligned} L_{z^-} &= I * (z^-/33)^{ep} \\ &= 500 * (15/33)^{0.2} \\ &= 427.0566 \end{aligned}$$

$$\begin{aligned} Q-2 &= 1 / (1 + 0.63 * ((b + h) / L_{z^-})^{0.63}) \\ &= 1 / (1 + 0.63 * ((0.1979167 + 5.029533) / 427.0566)^{0.63}) \\ &= .9621639 \end{aligned}$$

$$\begin{aligned} V_{z^-} &= b^- * (z^-/33)^a * V_{ref} \\ &= 0.65 * (15/33)^{0.1538462} * 161.3333 \\ &= 92.88744 \end{aligned}$$

$$\begin{aligned} N_I &= nI * L_{z^-} / V_{z^-} \\ &= 6.25 * 427.0566 / 92.88744 \\ &= 28.73482 \end{aligned}$$

$$\begin{aligned} R_n &= 7.465 * N_1 / ((1 + 10.302 * N_1)^{(5/3)}) \\ &= 7.465 * 28.73482 / ((1 - 10.302 * 28.73482)^{(5/3)}) \\ &= 1.622236E-02 \end{aligned}$$

$$\begin{aligned} R_h &= 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ &= 1/1.556713 - (1/(2*1.556713^2)) * (1 - e^{(-2*1.556713)}) \\ &= .4452245 \end{aligned}$$

$$\begin{aligned} R_b &= 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ &= 1/6.125806E-02 - (1/(2*6.125806E-02^2)) * (1 - e^{(-2*6.125806E-02)}) \\ &= .9603821 \end{aligned}$$

$$\begin{aligned} R_d &= 1/n - (1/(2*n^2)) * (1 - e^{(-2*n)}) \\ &= 1/0.2050813 - (1/(2*0.2050813^2)) * (1 - e^{(-2*0.2050813)}) \\ &= .8762227 \end{aligned}$$

$$\begin{aligned} R^2 &= (1/beta) * R_n * R_h * R_b * (0.53 + .47 * R_d) \\ &= (1/0.02) * 1.622236E-02 * 0.4452245 * 0.9603821 * (0.53 + .47 * 0.8762227) \\ &= .3266459 \end{aligned}$$

$$\begin{aligned} G &= (1 + 2*g*I_{z^-} * Sqr(Q^2 + R^2)) / (1 + 7*I_{z^-}) \\ &= (1 + 2*3.5 * 0.228087 * Sqr(0.9621639 + 0.3266459)) / (1 + 7 * 0.228087) \end{aligned}$$

Wind Calculations

= 1.083168

Velocity Pressure Coefficients, Kz and qz

Height (ft)	Z Kz	qz = 0.00256*Kz*Kzt*V^2*1
15.0	0.85	26.32

Design Wind Force determined from:  $F = qz * Gf * Cf * Af$

Stresses due to Wind + Hydrotest pressure, New

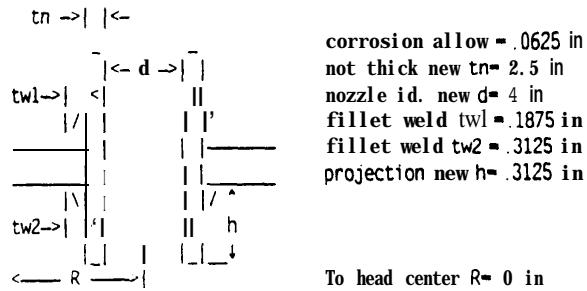
Elevation above base (in.)	Type	Minimum (thickness) joint	Circ eff. (in.)	Required thickness E	Overhead weight (lbs)	Bending moment (lb-ft)
22.50	cyl	0.3750	1.00		796.51	109.21
2.00	trans	0.3750	1.00		2894.01	249.5
0.00	cyl	0.4360	0.70		2895.5)	264.41

Table Continues	Maximum tensile stress/E	Allowable tensile stress (psi)	Maximum compressive stress (psi)	Allowable compressive stress (psi)	Hydro Pressure (psi)
	(psi)	(psi)	E=1 (psi)	(psi)	
	9789.4	30000.0*0.3	19.8	12053.2*1.2	188.5
	13290.2	30000.0*0.9	5117.2	14883.6*1.2	189.2
I	2140.8	30000.0*0.9	3554.9	15236.7*1.2	189.3

N1Opening N1 Reinforcement Calculations Per UG37

Located on: TPHEAD  
 Local vessel thickness: .25 in  
 Liquid static head included: 0 psi  
 Flange description: Not installed

Nozzle material specification: SA 240 3 16 HIGH  
 Nozzle orientation: 0 degrees  
 End of nozzle to datum line: 68.21906 in  
 Nozzle calculated as hillside: no  
 Projection outside vessel Lpr: 6 in

Reinforcement Calculations For Nozzle MAWPLimits of reinforcement UG-40

Parallel to the vessel wall ( $R_n + t_n + t$ ) = 4.6875 in  
 Normal to the vessel wall outside  $2.5*(t-C) = .46875$  in  
 Normal to the vessel wall inside  $2.5*(t-C) = .46875$  in

Nozzle required thickness

$$\begin{aligned} t_{rn} &= P * R_n / (S_n * E - 0.6 * P) \\ &= 125 * 2.0625 / (18050 * 1 - 0.6 * 125) \\ &= 0.0143 \text{ in} \end{aligned}$$

Required thickness tr from UG-37(a)(3)

$$\begin{aligned} t_r &= P * K_1 * D / (2 * S * E - 0.2 * P) \\ &= 125 * 0.9 * 39.5 / (2 * 18050 * 1 - 0.2 * 125) \\ &= 0.1232 \text{ in} \end{aligned}$$

Area required

Allowable stresses:  $S_n = 18050$ ,  $S_v = 18050$ , psi

$f_{rl1}$  = lesser of 1 or  $S_n/S_v$  so  $f_{rl1} = 1$   
 $f_{rl2}$  = lesser of 1 or  $S_n/S_v$  so  $f_{rl2} = 1$

$$\begin{aligned} A &= d * t_r * F + 2 * t_n * t_r * F * (1 - f_{rl}) \\ &= 4.125 * 0.1232 * 1 + 2 * 2.4375 * 0.1232 * 1 * (1 - 1) \\ &= .5082 \text{ in}^2 \end{aligned}$$

Area available

$$A_l = \text{larger of the following} = .338 \text{ in}^2$$

$$\begin{aligned} &= d * (E_1 * t - F * t_r) * 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{rl}) \\ &= 4.125 * (1 * 0.1875 - 1 * 0.1232) * 2 * 2.4375 * (1 * 0.1875 - 1 * 0.1232) * (1 - 1) \\ &= .265 \text{ in}^2 \\ &= 2 * (t + t_n) * (E_1 * t - F * t_r) - 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{rl}) \\ &= 2 * (0.1875 + 2.4375) * (1 * 0.1875 - 1 * 0.1232) - \end{aligned}$$

N1

$$= .338 \text{ in}^2$$

A2 = smaller of the following

$$\begin{aligned}
 &= 5 * (\text{tn} - \text{trn}) * \text{fr2} * \text{t} \\
 &= 5 * (2.4375 - 0.0143) * 1 * 0.1875 \\
 &= 2.272 \text{ in}^2
 \end{aligned}$$

$$= 2 * (t_n - t_m) * f_r^2 * L_p r$$

$$= 2 * (2.4375 - 0.0143) * 1 * 6$$

$$= 29.078 \text{ in}^2$$

$$\begin{aligned} A_3 &= 2 * (\pi n - c) * \pi r^2 * h \\ &= 2 * (2.4375 - 0.0625) * 1 * 0.25 \\ &= 1.188 \text{ in}^2 \end{aligned}$$

$$A41 = \text{Leg}^2 * \text{fr2} \\ = 0.1875^2 * 1 = .035 \text{ in}^2$$

$$A43 = \text{Leg}^2 * \text{fr2} \\ = 0.2232143^2 * 1 = .05 \text{ in}^2$$

$$\begin{aligned} \text{Area} &= A1 + A2 + A3 + A4 \\ &= 0.338 + 2.272 + 1.188 + 0.035 + 0.05 \\ &= 3.883 \text{ in}^2 \end{aligned}$$

As Area > A the reinforcement is adequate for MAWP = 125 at 450 Deg F

**Check the welds - From UW-16(d):**

tmin = lesser of 0.75 or tn or t, tmin = 0.1875 in  
 t1 or t2(min) = lesser of 0.25 or 0.7\*tmin, t1(min) = 0.13125 in  
 t1(actual) = 0.7\*Leg = 0.7\*0.1875 = 0.13125 in  
 t2(actual) = 0.7\*Leg = 0.7\*0.2232143 = 0.15625 in  
 tc(min) = lesser of 0.25 or 0.7\*tmin, tc(min) = 0.13125 in  
 tc(actual) = 0.7\*Leg = 0.7\*0.2232143 = 0.15625 in

$$t1 + t2 = 0.2875 \geq 1.25*tmin$$

The weld sizes for  $t_1$  and  $t_2$  are satisfactory.

## UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	$tr1 = 0.0768 \text{ in } (E = 1)$
Wall thickness per UG-45(b)(1):	$tr2 = 0.1857 \text{ in}$
Wall thickness per UG-16(b):	$tr3 = 0.125 \text{ in}$
Std pipe wall per UG-45(b)(4):	$tr4 = 0.381875 \text{ in}$
The greater of $tr2$ or $tr3$ :	$tr5 = 0.1857 \text{ in}$
The lesser of $tr4$ or $tr5$ :	$tr6 = 0.1857 \text{ in}$

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1857 in

Available nozzle wall thickness new,  $t_n = 2.5$  in

The nozzle neck thickness is adequate for MAWP.

### Allowable stresses in joints UG-45(c) and UW-15(c)

$$\begin{aligned}\text{Nozzle wall in shear} &= 0.7 * 18050 = 12635 \text{ psi} \\ \text{Inner fillet weld in shear} &= 0.49 * 18050 = 8844.5 \text{ psi} \\ \text{Lower fillet weld in shear} &= 0.49 * 18050 = 8844.5 \text{ psi}\end{aligned}$$

### **Strength of welded joints:**

$$(1) \text{ Inner fillet weld in shear} \\ (\text{Pi}/2) * \text{Nozzle O.D.} * \text{Leg} * \text{Si} = 1.57 * 9 * 0.1875 * 8844.5 = 23432.4 \text{ lbf}$$

### (3) Nozzle wall in shear

N1

$$(\frac{\pi}{2}) * \text{Mean nozzle dia.} * t_n * S_n = 1.57 * 6.5625 * 2.4375 * 12635 = 317313.7 \text{ lbf}$$

(5) Lower fillet weld in shear

$$(\frac{\pi}{2}) * \text{Nozzle O.D.} * t_w * S_g = 1.57 * 9 * 0.2232143 * 8844.5 = 27895.71 \text{ lbf}$$

**Loading on welds per UG-41(b)(1)**

$$\begin{aligned} W &= (A - A_1 + 2 * t_n * f_{r1} * (E_1 * t - F * t_r)) * S_v \\ &= (0.5082 - 0.338 + 2 * 2.4375 * 1 * (1 * 0.1875 - 1 * 0.1232)) * 18050 \\ &= 8730.108 \text{ lbf} \end{aligned}$$

$$\begin{aligned} W_{1-1} &= (A_2 + A_5 + A_{41} + A_{42}) * S_v \\ &= (2.272 + 0 + 0.035 + 0) * 18050 \\ &= 41641.35 \text{ lbf} \end{aligned}$$

$$\begin{aligned} W_{2-2} &= (A_2 + A_3 + A_{41} + A_{43} + 2 * t_n * t * f_{r1}) * S_v \\ &= (2.272 + 1.188 + 0.035 + 0.05 + 2 * 2.4375 * 0.1875 * 1) * 18050 \\ &= 80486.08 \text{ lbf} \end{aligned}$$

Load for path 1-1 lesser of W or W<sub>1-1</sub> = 8730.108 lbf

Path 1-1 Thru (1) & (3) = 23432.4 + 317313.7 = 340746.1 lbf

Path 1-1 is stronger than W so it is acceptable per UG-41(b)(2).

Load for path 2-2 lesser of W or W<sub>2-2</sub> = 8730.108 lbf

Path 2-2 Thru (1), (5) = 23432.4 + 27895.71 = 51328.11 lbf

Path 2-2 is stronger than W so it is acceptable per UG-41(b)(2).

**Reinforcement Calculations for External Pressure****Limits of reinforcement UG-40**

Parallel to the vessel wall ( $R_n + t_n - t$ ) = 4.6875 in  
 Normal to the vessel wall outside  $2.5 * (t - C) = .46875$  in  
 Normal to the vessel wall inside  $2.5 * (t - C) = .46875$  in

**Nozzle required thickness**

$$\begin{aligned} L/Do &= 6/9 = .6667 & Do/t &= 9/0.02484 = 362.3188 \\ \text{From table G:} & & A &= 0.000302 \\ \text{From table HA-2:} & & B &= 4095 \end{aligned}$$

$$\begin{aligned} P_a &= 4 * B / (3 * Do/t) \\ &= 4 * 4095 / (3 * 9 / 0.02484) \\ &= 15.0696 \text{ psi} \end{aligned}$$

Nozzle required thickness  $t_m = .02484$  in

**Required thickness tr from UG-37(d)(1) = .1052 in****Area required**

Allowable stresses:  $S_n = 18800$ ,  $S_v = 18800$ , psi

$f_{r1}$  = lesser of 1 or  $S_n/S_v$  so  $f_{r1} = 1$

$f_{r2}$  = lesser of 1 or  $S_n/S_v$  so  $f_{r2} = 1$

$$\begin{aligned} A &= 0.5 * (d * t_r * F + 2 * t_n * t_r * F * (1 - f_{r1})) \\ &= 0.5 * (4.125 * 0.1052 * 1 + 2 * 2.4375 * 0.1052 * 1 * (1 - 1)) \\ &= .217 \text{ in}^2 \end{aligned}$$

**Area available**

$$A_1 = \text{larger of the following} = .432 \text{ in}^2$$

$$\begin{aligned} &= d * (E_1 * t - F * t_r) - 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{r1}) \\ &= 4.125 * (1 * 0.1875 - 1 * 0.1052) - 2 * 2.4375 * (1 * 0.1875 - 1 * 0.1052) * (1 - 1) \\ &= .339 \text{ in}^2 \end{aligned}$$

$$= 2 * (t + t_n) * (E_1 * t - F * t_r) - 2 * t_n * (E_1 * t - F * t_r) * (1 - f_{r1})$$

N1

$$\begin{aligned}
 &= 2 * (0.1875 + 2.4375) * (1 * 0.1875 - 1 * 0.1052) - \\
 &\quad 2 * 2.4375 * (1 * 0.1875 - 1 * 0.1052) * (1 - 1) \\
 &= .432 \text{ in}^2
 \end{aligned}$$

$$A2 = \text{smaller of the following} \quad = 2.262 \text{ in}^2$$

$$\begin{aligned}
 &= 5 * (tn - trn) * fr2 * t \\
 &= 5 * (2.4375 - 0.02484) * 1 * 0.1875 \\
 &= 2.262 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 &= 2 * (tn - trn) * fr2 * Lpr \\
 &= 2 * (2.4375 - 0.02484) * 1 * 6 \\
 &= 28.952 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A3 &= 2 * (tn - c) * fr2 * h \\
 &= 2 * (2.4375 - 0.0625) * 1 * 0.25 \\
 &= 1.188 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A41 &= \text{Leg}^2 * fr2 \\
 &= 0.1875^2 * 1 = .035 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 A43 &= \text{Leg}^2 * fr2 \\
 &= 0.2232143^2 * 1 = .05 \text{ in}^2
 \end{aligned}$$

$$\begin{aligned}
 \text{Area} &= A1 + A2 + A3 + A41 + A43 \\
 &= 0.432 + 2.262 + 1.188 + 0.035 + 0.05 \\
 &= 3.967 \text{ in}^2
 \end{aligned}$$

As Area > A the reinforcement is adequate for Pe = 15 at 0 Deg F

**UG-45 Nozzle Neck Thickness Check**

Wall thickness per UG-45(a):	tr1 = 0.08734 in (E = 1)
Wall thickness per UG-45(b)(2):	tr2 = 0.0767 in
Wall thickness per UG-16(b):	tr3 = 0.125 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.381875 in
The greater of tr2 or tr3:	tr5 = 0.125 in
The lesser of tr4 or tr5:	tr6 = 0.125 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.125 in

Available nozzle wall thickness new. tn = 2.5 in

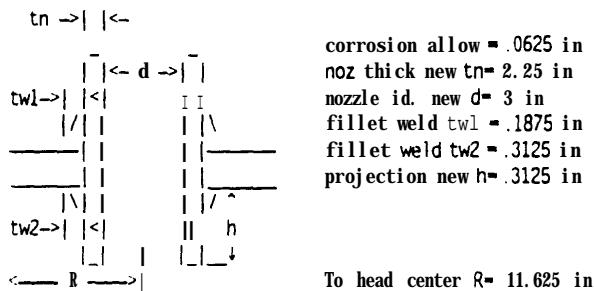
The nozzle neck thickness is adequate for Pe.

N2Opening N2 Reinforcement Calculations Per UG37

Located on: TPHEAD  
 Local vessel thickness: .25 in  
 Liquid static head included: .04 psi  
 Flange description: Not installed

Nozzle material specification: SA 240 3 16 HIGH

Nozzle orientation: 0 degrees  
 End of nozzle to datum line: 68.21906 in  
 Nozzle calculated as hillside: no  
 Projection outside vessel Lpr: 7.777 in

Reinforcement Calculations For Nozzle MAWPLimits of reinforcement UG-40

Parallel to the vessel wall ( $R_n + t_n + t$ ) = 3.9375 in  
 Normal to the vessel wall outside  $2.5*(t-C)$  = .46875 in  
 Normal to the vessel wall inside  $2.5*(t-C)$  = .46875 in

Nozzle required thickness

$$\begin{aligned} tr_n &= P * R_n / (S_n * E - 0.6 * P) \\ &= 125.04 * 1.5625 / (18050 * 1 - 0.6 * 125.04) \\ &= 0.0109 \text{ in} \end{aligned}$$

Required thickness tr from UG-37(a)(3)

$$\begin{aligned} tr &= P * K_1 * D / (2 * S * E - 0.2 * P) \\ &= 125.04 * 0.9 * 39.5 / (2 * 18050 * 1 - 0.2 * 125.04) \\ &= 0.1232 \text{ in} \end{aligned}$$

Opening does not require reinforcement per UG-36(c)(3)(a)Check the welds - From UW-16(d):

$$\begin{aligned} t_{min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t, t_{min} = 0.1875 \text{ in} \\ t_1 \text{ or } t_2(\min) &= \text{lesser of } 0.25 \text{ or } 0.7 * t_{min}, t_1(\min) = 0.13125 \text{ in} \\ t_1(\text{actual}) &= 0.7 * \text{Leg} = 0.7 * 0.1875 = 0.13125 \text{ in} \\ t_2(\text{actual}) &= 0.7 * \text{Leg} = 0.7 * 0.2232143 = 0.15625 \text{ in} \\ t_c(\min) &= \text{lesser of } 0.25 \text{ or } 0.7 * t_{min}, t_c(\min) = 0.13125 \text{ in} \\ t_c(\text{actual}) &= 0.7 * \text{Leg} = 0.7 * 0.2232143 = 0.15625 \text{ in} \end{aligned}$$

$$t_1 + t_2 = 0.2875 >= 1.25 * t_{min}$$

The weld sizes for  $t_1$  and  $t_2$  are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $tr_1 = 0.0734 \text{ in } (E = 1)$   
 Wall thickness per UG-45(b)(1):  $tr_2 = 0.1857 \text{ in}$   
 Wall thickness per UG-16(b):  $tr_3 = 0.125 \text{ in}$   
 Std pipe wall per UG-45(b)(4):  $tr_4 = 0.34425 \text{ in}$

N2

The greater of tr2 or tr3:                   tr5 = 0.1857 in  
 The lesser of tr4 or tr5:                   tr6 = 0.1857 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.1857 in

Available nozzle wall thickness new, tn = 2.25 in

The nozzle neck thickness is adequate for MAWP.

Exempt from weld strength calculations per UW-15(b)(2)

**Reinforcement Calculations for External Pressure****Limits of reinforcement UG-40**

Parallel to the vessel wall (Rn + tn + t) = 3.9375 in  
 Normal to the vessel wall outside 2.5\*(t-C) = .46875 in  
 Normal to the vessel wall inside 2.5\*(t-C) = .46875 in

**Nozzle required thickness**

$$\begin{aligned} L/Do &= 7.777/7.5 = 1.0369 & Do/t &= 7.5/0.02528 = 296.6772 \\ \text{From table G:} & & A &= 0.00025 \\ \text{From table HA-2:} & & B &= 3370.8 \end{aligned}$$

$$\begin{aligned} Pa &= 4*B/(3*Do/t) \\ &= 4*3370.8/(3*7.5/0.02528) \\ &= 15.1491 \text{ psi} \end{aligned}$$

Nozzle required thickness tm = .02528 in

**Required thickness tr from UG-37(d)(1) = .1052 in****Opening does not require reinforcement per UG-36(c)(3)(a)****UG-45 Nozzle Neck Thickness Check**

Wall thickness per UG-45(a):	tr1 = 0.08778 in (E = l)
Wall thickness per UG-45(b)(2):	tr2 = 0.0767 in
Wall thickness per UG-16(b):	tr3 = 0.125 in
Std pipe wall per UG-45(b)(4):	tr4 = 0.34425 in
The greater of tr2 or tr3:	tr5 = 0.125 in
The lesser of tr4 or tr5:	tr6 = 0.125 in

Req'd per UG-45 is the larger of tr1 or tr6 = 0.125 in

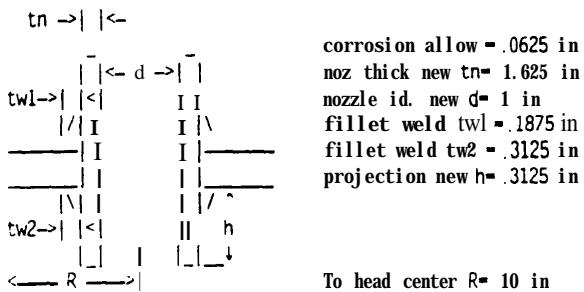
Available nozzle wall thickness new, tn = 2.25 in

The nozzle neck thickness is adequate for Pe.

Exempt from weld strength calculations per UW-15(b)(2)

N3Opening N3 Reinforcement Calculations Per UG37

Located on: TPHEAD  
 Local vessel thickness: .25 in  
 Liquid static head included: 0 psi  
 Flange description: Not installed  
 Nozzle material specification: SA 240 3 16 HIGH  
 Nozzle orientation: 180 degrees  
 End of nozzle to datum line: 68.21906 in  
 Nozzle calculated as hillside: no  
 Projection outside vessel Lpr: 7.121 in

Reinforcement Calculations For Nozzle MAWPLimits of reinforcement UG-40

Parallel to the vessel wall ( $R_n + t_n + t$ ) = 2.3125 in  
 Normal to the vessel wall outside  $2.5*(t-C)$  = .46875 in  
 Normal to the vessel wall inside  $2.5*(t-C)$  = .46875 in

Nozzle required thickness

$$\begin{aligned} t_{rn} &= P * R_n / (S_n * E - 0.6 * P) \\ &= 125 * 0.5625 / (18050 * 1 - 0.6 * 125) \\ &= 0.0039 \text{ in} \end{aligned}$$

Required thickness tr from UG-37(a)(3)

$$\begin{aligned} t_r &= P * K_1 * D / (2 * S * E - 0.2 * P) \\ &= 125 * 0.9 * 39.5 / (2 * 18050 * 1 - 0.2 * 125) \\ &= 0.1232 \text{ in} \end{aligned}$$

Opening does not require reinforcement per UG-36(c)(3)(a)Check the welds - From UW-16(d):

$$\begin{aligned} t_{min} &= \text{lesser of } 0.75 \text{ or } t_n \text{ or } t, t_{min} = 0.1875 \text{ in} \\ t_l \text{ or } t_2(\min) &= \text{lesser of } 0.25 \text{ or } 0.7*t_{min}, t_l(\min) = 0.13125 \text{ in} \\ t_1 \text{ (actual)} &= 0.7 * \text{Leg} = 0.7 * 0.1875 = 0.13125 \text{ in} \\ t_2 \text{ (actual)} &= 0.7 * \text{Leg} = 0.7 * 0.2232143 = 0.15625 \text{ in} \\ t_c(\min) &= \text{lesser of } 0.25 \text{ or } 0.7*t_{min}, t_c(\min) = 0.13125 \text{ in} \\ t_c(\text{actual}) &= 0.7 * \text{Leg} = 0.7 * 0.2232143 = 0.15625 \text{ in} \end{aligned}$$

$$t_1 + t_2 = 0.2875 > = 1.25 * t_{min}$$

The weld sizes for  $t_l$  and  $t_2$  are satisfactory.

UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):  $t_{rl} = 0.0664 \text{ in } (E = 1)$   
 Wall thickness per UG-45(b)(1):  $t_{r2} = 0.1857 \text{ in}$   
 Wall thickness per UG-16(b):  $t_{r3} = 0.125 \text{ in}$   
 Std pipe wall per UG-45(b)(4):  $t_{r4} = 0.269875 \text{ in}$

N3

The greater of tr2 or tr3:  $tr5 = 0.1857$  in  
 The lesser of tr4 or tr5:  $tr6 = 0.1857$  in

Req'd per UG-45 is the larger of tr1 or  $tr6 = 0.1857$  in

Available nozzle wall thickness new,  $tn = 1.625$  in

The nozzle neck thickness is adequate for **MAWP**.

Exempt from weld strength calculations per UW-15(b)(2)

### Reinforcement Calculations for External Pressure

#### Limits of reinforcement UG-40

Parallel to the vessel wall ( $Rn + tn + t$ ) = 2.3125 in  
 Normal to the vessel wall outside  $2.5*(t-C) = .46875$  in  
 Normal to the vessel wall inside  $2.5*(t-C) = .46875$  in

#### Nozzle required thickness

$$\begin{aligned} L/Do &= 7.121/4.25 = 1.6755 & Do/t &= 4.25/0.01745 = 243.553 \\ \text{From table G:} & A = 0.000206 \\ \text{From table HA-2:} & B = 2761.4 \end{aligned}$$

$$\begin{aligned} Pa &= 4*B/(3*Do/t) \\ &= 4*2761.4/(3*4.25/0.01745) \\ &= 15.1173 \text{ psi} \end{aligned}$$

Nozzle required thickness  $tm = .01745$  in

#### Required thickness tr from UG-37(d)(1) = .1052 in

#### Opening does not rewire reinforcement per UG-36(c)(3)(a)

#### UG-45 Nozzle Neck Thickness Check

Wall thickness per UG-45(a):	$tr1 = 0.07995$ in (E = 1)
Wall thickness per UG-45(b)(2):	$tr2 = 0.0767$ in
Wall thickness per UG-16(b):	$tr3 = 0.125$ in
Std pipe wall per UG-45(b)(4):	$tr4 = 0.269875$ in
The greater of tr2 or tr3:	$tr5 = 0.125$ in
The lesser of tr4 or tr5:	$tr6 = 0.125$ in

Req'd per UG-45 is the larger of tr1 or  $tr6 = 0.125$  in

Available nozzle wall thickness new,  $tn = 1.625$  in

The nozzle neck thickness is adequate for Pe.

Exempt from weld strength calculations per UW-15(b)(2)

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Pressure SummaryPressure summary for pressure chamber 1

Identifier	I	P	I	T	MAWP	MAP	Pe	UG-99	UCS-66	Corrosion
	design	design	(deg F)	(psi)	(psi)	(psi)	external	Ratio	MOMT	Exemption or Allowance
	(psi)							(deg F)	Stress Reduction	(in)
TPHEAD	125.0	-	450.0	-	169.9	236.9	0.0	1.042	-	Not applicable
SHELL	125.0	-	450.0	-	281.0	352.4	0.0	1.042	-	Not applicable
TEMPHD	125.0	-	450.0	-	167.0	234.0	0.0	1.042	-	Not applicable
Wind Calculations	-	-	-	-	167.0	-	0.0	-	-	-

Vessel MAWP hot & corroded is 167.06 psi @ 450 degrees F.

Vessel MAP new & cold is 234.07 psi @ 70 degrees F.

Vessel is not designed for external pressure.

Hydrotest pressure calculation based on P

$$= 1.5 * P * 1.042 = \cancel{195.4} \text{ psi } 202$$

*(Signature) 2/13/98*

Vessel hydrotest pressure, horizontal position is ~~195.4~~ psi.

*202*

Design notes:

Minimum thickness is 1/16 inch per UG-16(b).

Corrosion weight loss is 100% of theoretical loss.

UG-23 stress increase is 1.2.

Support legs stress increase is 1.2.

33% of design wind load used for field hydrotest.

Test liquid specific gravity is 1.

Minimum nozzle outside projection 6 inches.

Maximum stress allowed during field hydrotest is 90% of yield.

Butt weld thickness transitions made by removing material.

P-No 1 material > 1.25 to 1.5 in. thick IS preheated (UCS-56).

LEGSWind/weight in the operating, corroded condition governs.

Note: Formulae are taken from the **AISC** manual ninth edition.

Weight supported by legs: 4706.689 lb  
 Moment supported by legs: 259.8227 lb-ft  
 Total base shear: 164.7297 lb

Leg material: **SA-479-316**  
 Leg description: **3x3x3/8 Equal Angle (Leg in)**  
 Number of legs: 4  
 Overall length: 52.6875 in  
 Base to girth seam length: 40.6875 in

Eccentricity of loading: **.8655** in  
 Bolt circle: 40 in  
 Leg area: 2.11 in<sup>2</sup>  
 Effective length coeff. K: 1.5 (AISC 5-39)  
 Coefficient Cm: **.85 (AISC 5-55)**  
 Leg yield stress Fy: **36000** psi  
 Leg elastic modulus E: 29000000 psi

Eccentric end load on leg

$$\begin{aligned} P_1 &= W/N + 4*12*Mt/(N*D) \\ &= 4706.68914 + 4*12*259.8227/(4*40) \\ &= 1254.619 \text{ lb} \end{aligned}$$

Allowable axial compressive stress, Fa (AISC chapter E)

Local buckling check (AISC 5-99)

b/t < 76 / Sqr(Fy/1000) so Qs = 1.0

Flexural-torsional buckling (AISC 5-3 17)

Shear center distance wo = 0.9906566  
 Torsional constant J = **9.890625E-02**  
 Shear modulus G = 11165000 psi

$$\begin{aligned} ro2 &= wo^2 + (Iz + Iw)/A \\ &= 0.9906566^2 + (0.7263723 + 2.79356)/2.11 \\ &= 2.649615 \end{aligned}$$

$$\begin{aligned} H &= 1 - wo^2/ro2 \\ &= 1 - 0.9906566^2/2.649615 \\ &= .6296064 \end{aligned}$$

$$\begin{aligned} Fej &= G*J/(A*ro2) \\ &= 11165*9.890625E-02/(2.11*2.649615) \\ &= 197.5228 \end{aligned}$$

$$K*I/rw = 1.5*40.6875/1.150635 = 53.04134$$

$$\begin{aligned} Few &= pi^2*E/(Kl/r)^2 \\ &= pi^2*29000/(53.04134)^2 \\ &= 101.7346 \end{aligned}$$

$$\begin{aligned} Fe &=((Few + Fej)/(2*H))*(1 - Sqr(1 - (4*Few*Fej*H)/(Few + Fej)^2)) \\ &=((101.7346 + 197.5228)/(2*0.6296064))*(1 - Sqr(1 - (4*101.7346*197.5228*0.6296064)/(101.7346 + 197.5228)^2)) \\ &= 80.92856 \end{aligned}$$

Equivalent slenderness ratio

$$\begin{aligned} Kl/r &= pi*Sqr(E/Fe) \\ &= pi*Sqr(29000/80.92856) \\ &= 59.47001 \end{aligned}$$

LEGS

$$\begin{aligned} C_c &= \text{Sqr}(2*\pi^2*E/(F_y*Q_s)) \\ &= \text{Sqr}(2*\pi^2*29000000/(36000*1)) \\ &= 126.0993 \end{aligned}$$

$$\begin{aligned} F_a &= 1.2 * (1 - (K_l/r)^2/(2*C_c^2)) * F_y / \\ &\quad (5/3 + 3*(K_l/r)/(8*C_c) - (K_l/r)^3/(8*C_c^3)) \\ &= 1.2 * (1 - (104.0193)^2/(2*126.0993^2)) * 36000 / \\ &\quad (5/3 + 3*(104.0193)/(8*126.0993) - (104.0193)^3/(8*126.0993^3)) \\ &= 14955.12 \text{ psi} \end{aligned}$$

Allowable axial compression and bending (AISC chapter H)

$r$  is divided by 1.35 - See AISC 6.1.4, pg. 5-3 14

$$\begin{aligned} F'_{ex} &= 1.2 * 12*\pi^2*E/(23*(K_l/r)^2) \\ &= 1.2 * 12*\pi^2*29000000/(23*(140.426)^2) \\ &= 9087.352 \text{ psi} \end{aligned}$$

$r$  is divided by 1.35 - See AISC 6.1.4, pg. 5-3 14

$$\begin{aligned} F'_{ey} &= 1.2 * 12*\pi^2*E/(23*(K_l/r)^2) \\ &= 1.2 * 12*\pi^2*29000000/(23*(71.60581)^2) \\ &= 34949.1 \text{ psi} \end{aligned}$$

$$\begin{aligned} F_b &= 1.2 * 0.66 * F_y \\ &= 285.12 \text{ psi} \end{aligned}$$

Leg at orientation 180 degrees governs.

Compressive axial stress

$$f_a = P_l/A = 1254.619/2.11 = 594.6063 \text{ psi}$$

Bending stresses

$$\begin{aligned} t_{bx} &= F * \text{Cos}(\alpha) * L / (I_x/C_x) + P_1 * E_{cc} / (I_x/C_x) \\ &= 4.18166 * \text{Cos}(225) * 40.6875 / (0.7263723 / 0.8654782) + \\ &\quad 1254.619 * 0.8655 / (0.7263723 / 0.8654782) \\ &= 2705.539 \text{ psi} \end{aligned}$$

$$\begin{aligned} t_{by} &= F * \text{Sin}(\alpha) * L / (I_y/C_y) \\ &= 41.18166 * \text{Sin}(225) * 40.6875 / (2.79356 / 2.1213) \\ &= 899.6925 \text{ psi} \end{aligned}$$

AISC equation H1-1

$$\begin{aligned} f_a/F_a + C_{mx}*t_{bx}/((1-f_a/F'_{ex})*F_{bx}) + C_{my}*t_{by}/((1-f_a/F'_{ey})*F_{by}) \\ &= 594.6063/14955.12 + 0.85*2705.539/((1-594.6063/9087.352)*28512) + \\ &\quad 0.85*899.6925/((1-594.6063/34949.1)*28512) \\ &= .1533499 \end{aligned}$$

AISC equation H1-2

$$\begin{aligned} f_a/(0.6*1.2*F_y) + t_{bx}/F_{bx} + t_{by}/F_{by} \\ &= 594.6063/(0.6*1.2*36000) + 2705.539/28512 + 899.6925/28512 \\ &= .1493862 \end{aligned}$$

3x3x3/8 Equal Angle legs are adequate.Angle properties (AISC 6-23)

$$K = abcdt/(4(b+c)) = 1.033594$$

$$\begin{aligned} I_x &= I_{xx} * \text{Sin}(45)^2 + I_{yy} * \text{Cos}(45)^2 - K * \text{SIN}(2 * 45) \\ &= 1.76 * \text{Sin}(45)^2 + 1.76 * \text{Cos}(45)^2 - 1.033594 * \text{SIN}(2 * 45) \\ &= .7263723 \text{ in}^4 \end{aligned}$$

$$\begin{aligned} I_y &= I_x + 2 * K * \text{SIN}(2 * 45) \\ &= 0.7263723 + 2 * 1.033594 * \text{SIN}(2 * 45) \end{aligned}$$

LEGS

= 2.79356 in<sup>4</sup>

0  
X-X Note: Axis X-X is tangent to the vessel surface.  
axis Y-Y is perpendicular to axis X-X  
270 > 90

I  
180

Force attack angle 0 degrees								
Orient degrees	Inertia in <sup>4</sup>	Shear lbf	Axial fa. psi	Bending fbx psi	Bending fby psi	Eq Ratio	H1-1 Eq	H1-2 Ratio
0	0.72	16.9	594.6	2117.8	0.0	.1073	.0972	
90	2.79	65.3	594.6	1293.8	2019.5	.1423	.1392	
180	0.72	16.9	594.6	2117.8	0.0	.1073	.0972	
270	2.79	65.3	594.6	1293.8	2019.5	.1423	.1392	

Force attack angle 45 degrees								
Orient degrees	Inertia in <sup>4</sup>	Shear lbf	Axial fa. psi	Bending fbx psi	Bending fby psi	Eq Ratio	H1-1 Eq	H1-2 Ratio
0	1.75	41.1	594.6	2705.5	899.6	.1533	1494	
90	1.75	41.1	594.6	2705.5	899.6	.1533	1494	
180	1.75	41.1	594.6	2705.5	899.6	.1533	1494	
270	1.75	41.1	594.6	2705.5	899.6	.1533	1494	

Anchor bolts - Wind/weight in the empty condition governs.

Tensile loading per leg (1 bolt(s) per leg)

$$\begin{aligned} R &= 48*M/(N*BC) - W/N \\ &= 48*818.3594/(4*40) - 760.689814 \\ &= 55.33536 \text{ lb} \end{aligned}$$

Required tensile area per bolt. Sb = 20000 psi

$$\begin{aligned} Ab &= R/(Sb*n) \\ &= 55.33536/(20000*1) \\ &= 2.766768E-03 \text{ in}^2 \end{aligned}$$

Area of 1" bolt = .551 in<sup>-2</sup>

1" bolts are satisfactory.

Check leg attachment stresses

Radial load	Pr = -65.3668 1 lbf
Circumferential moment	Mc = 0 lbf-ft
Circumferential shear	Vc = 0 lbf
Longitudinal moment	ML = 3 12.1237 lbf-ft
Longitudinal shear	VL = 1254.619 lbf
Internal pressure	P = 127.743 psi

Stresses at the leg edge per WRC bulletin 107 ( psi)

Mean radius Rm = 19.84375 in  
Rm/t = 63.5

C1 = 1.7118, C2 = 6.847199 in

Stress concentration factor Kn (tension) = 1  
Stress concentration factor Kb (bending) = 1

LEGS

Local circ. pressure stress =  $P \cdot R_m / t = 8112$  psi

Local long. pressure stress =  $P \cdot R_m / 2t = 4056$  psi

Maximum combined stress = 10206 psi

Allowable combined stress =  $\pm 3 \cdot S = \pm 54150$  psi

The maximum combined stress is within allowable limits.

Maximum primary membrane stress = 8630 psi

Allowable primary membrane stress =  $\pm 1.5 \cdot S = \pm 27075$  psi

The maximum primary membrane stress is within allowable limits.

LEGS

From	Value	beta)	Au	Al	Bu	B1	Cu	Cl	Du	D1
Fig. 1 read										
3C*	13.1665	10.2551					33	33	33	33
4C*	17.8451	0.207	83	83	83	83				
1C	10.0732	0.152					294	-294	294	-294
2C-1	0.0408	0.152	164	-164	164	-164				
3A*	12.4957	0.137								
1A	10.0741	(0.167								
3B*	15.3313	10.217	-435	-435	435	435				
1B-1	0.0224	10.184	-1412	1412	1412	-1412				
pressure stress*			8112	8112	8112	8112	8112	8112	8112	8112
Total circ stress			6512	9008	10206	7054	8439	7851	8439	7851
Primary membrane										
circ stress*			7760	7760	8630	8630	8145	8145	8145	8145
3C* 14.2982	0.207		45	45	45	45				
4C* (6.8684	(0.255					72	72	72	72	
1C-1	0.0489	0.216	196	-196	196	-196				
2c	10.0334	(0.216					134	-134	134	-134
4A*	14.4792	10.137								
2A	10.0297	0.216								
4B*	12.4239	10.217	-374	-374	374	374				
2B-1	0.0234	10.255	-1066	1066	1066	-1066				
pressure stress*			3056	4056	4056	4056	4056	4056	4056	4056
Total long stress			2857	4597	5737	3213	4262	3994	4262	3994
Primary membrane										
long stress*			3727	3727	4475	4475	4128	4128	4128	4128
torsion moment M <sub>t</sub>										
Circ shear from Vc							-147	-147	147	147
Long shear from VL										
Total Shear stress							-147	-147	147	147
Combined stress			6512	9008	10206	7054	8444	7857	3444	7857